



# **CLOSURE PLAN**

Yorktown Power Station Ash Landfill Permit #457



**Submitted To:** Dominion Energy – Yorktown Power Station

1600 Waterview Road Yorktown, Virginia 23692

Submitted By: Golder Associates Inc.

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Suite 200

Richmond, VA 23227

October 2017 Revised March 2018 1239-6405

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Table 1 Closure Schedule

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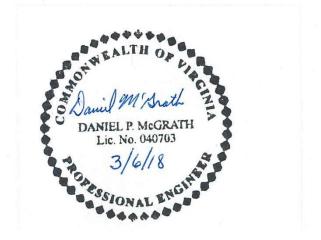
- Closure Design Plans and Calculations
   Revised Universal Soil Loss Equation (RUSLE)
- 8. Closure Cost Estimate

# 1.0 PLAN CERTIFICATION

I certify that the information contained within this Closure Plan was prepared by me or under my direct supervision, and meets the requirements of Section §257.102 of the Federal Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals (CCR) from Electric Utilities; Final Rule (40 CFR 257; the CCR rule) and the Virginia Solid Waste Management Regulations.

I also certify that the design of the final cover system described in this plan meets the requirements of Section §257.102(d)(3).

Daniel McGrath	Associate and Senier Consultant
Print Name	Title
Daniel M. Sath	3/6/18
Signature	Date



### 2.0 CLOSURE PURPOSE

This Closure Plan is written for the Yorktown Power Station Coal Combustion Residuals (CCRs) Landfill (landfill) at Dominion's Yorktown Power Station (Station) in York County, Virginia. It is anticipated that Dominion will cease coal fired electric power generation at the Yorktown Power Station in late 2019. Consequently, after the last ash is placed in the landfill, the solid waste landfill will be subject to closure under the Virginia Solid Waste Management Regulations at 9 VAC 20-81-160 and the Federal Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals From Electric Utilities; Final Rule (the CCR Final Rule), 40 CFR 257.

At the time of its closure, the landfill will not be at its design capacity grades and will contain approximately 1,400,000 cubic yards of CCR material. Dominion has prepared this revised Closure Plan to amend the final grading plan and closure schedule accordingly. The landfill is operated under the Virginia Department of Environmental Quality (DEQ) Solid Waste Permit No. 457 and the York County Conditional Use Permit [Resolution No. R82-221 (R2)].

# 2.1 General Landfill Information

Dominion has operated the landfill for disposal of CCRs produced at the Station since the early 1980's. The CCRs include fly ash, bottom ash, pyrites, and limestone injection multi-stage burner (LIMB) ash. The landfill is approximately two miles south of the Station on Wolftrap Road. The permitted area of the landfill comprises approximately 48 acres designated for placement of CCRs. The area is divided into 12 cells of the lower landfill and includes 4 phases in the vertical expansion. Cells 1 through 11 have received CCRs and are covered with intermediate cover soil. Cell 12 is currently open and active, and Phase 1 of the vertical expansion has been constructed for future expansion, but CCRs have not been placed in this area. Phases 2 – 4 of the vertical expansion have not been constructed.

The final cover system is designed to cover both the vertical expansion and lower landfill portions, and will be approximately 49 acres in total size. As of November 2017, 29.6 acres of the landfill (Phase 'A') have been closed.

Storm water runoff from the disposal units is conveyed to sedimentation ponds located along the eastern border of the landfill. Discharges from these ponds are regulated under a Virginia Pollutant Discharge Elimination System (VPDES) permit (Permit No. VA0004103) issued by DEQ.

Leachate is collected in perforated pipe and conveys leachate to a collection sump that is pumped directly to the Hampton Roads Sanitation District (HRSD) system.

# 2.2 Closure Plan Implementation

The goals of the closure plan design at the landfill are to provide a low maintenance cover system with appropriate stormwater runoff controls to prevent erosion and exposure of the CCRs. The maximum

permitted side slope is 3H:1V, and storm water benches are located to intercept sheet flow before it can concentrate into an erosive flow. The final cover soil will have a vigorous stand of vegetation established to minimize soil erosion. A Linear Low Density Polyethylene (LLDPE) geomembrane liner will serve as the infiltration barrier to prevent water percolation into the CCR.

The closure construction will take place in two phases. The first phase of closure (Phase A) includes approximately 29.6 acres and consists of closing cells 1-3 and 7-11. The final phase (Phase B) will include the remaining active cells, cells 12 and the vertical expansion. Closure of Phase B will close the remaining 19.2 acres. Construction for Phase A was substantially complete in November, 2017. Phase B closure will begin shortly after the facility ceases coal use for production of electricity and the last placement of ash has occurred. The existing storm water ponds will remain active following completion of the Phase B closure to receive and attenuate storm water flows from the landfill. Discharges for these ponds will continue to be permitted under the Station's VPDES Permit.

CCRs by their nature are non-putrescible, and do not decompose or produce landfill gas. Gas migration and odor is not anticipated to be a concern post-closure. The landfill's leachate system will continue to collect leachate and discharge it directly to the HRSD sanitary system via a leachate pump station. The leachate system that was constructed with Phase 1 of the vertical expansion will be disconnected and removed.

# 3.0 CLOSURE TIMEFRAMES

Phase A closure, as described above, was completed in November, 2017. The active area of the landfill [Cell 12] will continue to receive CCRs until the Station ceases coal fired power generation. The landfill will receive its last waste in conjunction with the shutdown and decommissioning of the Station's coal fired generating units. After the station's coal units are shutdown, the remaining CCR material will be removed from the Station and placed in the landfill.

Based upon historical CCR generation at the Station, the landfill has an estimated remaining disposal life of 23 years. It is anticipated that when the final CCR is placed in the landfill, Cell 12 will not be at its design capacity, nor will CCRs be placed in the vertical expansion.

# 4.0 CLOSURE OF SUPPORT PONDS AND BASINS

The storm water ponds at the landfill will remain in place to continue providing storm water attenuation for the site post-closure. Discharges for these ponds will continue to be permitted under the Station's VPDES Permit.

### 5.0 CLOSURE OF LANDFILL UNITS

# **5.1** Final Cover Design

The Final Cover system to be installed is as described in the landfill's solid waste permit #457. This cover system, in accordance with 9VAC20-81-160-D.2.e, consists of, from the bottom to the top:

- 40 mil LLDPE geomembrane;
- 250 mil Double-sided geocomposite drainage layer;
- A minimum 18-inch protective cover layer of compacted soil; and,
- A minimum 6-inch layer of vegetative support soil that is subsequently seeded.

The final cover system will be placed directly on the prepared subgrade after the intermediate cover soil vegetative cover is stripped and shaped as needed to achieve design grades and minimize the need for future maintenance. The Design Plans included in Attachment 2 show the final cover system. Technical Specifications and the Construction Quality Assurance (CQA) plan for the closure system components are in the landfill permit.

The final cover system design as proposed will also conform with requirements in the CCR rule at 40 CFR 257.102(d)(1) and (3).

# 5.1.1 Barrier Layer

The barrier layer is a 40-mil, Linear Low Density textured polyethylene geomembrane (LLDPE). Section 02597 of the Technical Specifications describes the material requirements, installation and seaming procedures, and CQA documentation to be recorded during construction of the barrier layer.

# 5.1.2 Geocomposite Drainage Layer

To provide drainage for the cover soils, a 250-mil geocomposite drainage layer will be placed on top of the geomembrane. The geonet core will be faced on both sides with a nonwoven geotextile to provide filtration and prevent the intrusion of soil into the core. At the toe of slope, the geocomposite will discharge directly into the perimeter drainage channel. Intermediate drains for the geocomposite are proposed to limit the drainage length to 350 feet to prevent saturation of the cover soils.

# 5.1.3 Protective Cover Layer and Vegetative Support Layer

Immediately above the geocomposite drainage layer, a 24-inch thick layer of soil will be placed to serve as the Protective Cover and Vegetative Support layer (18-inches of protective cover and 6-inches of vegetative support soil). The soil will be imported into the site from an offsite borrow source. Acceptable soil types for this layer are: GM, GC, SM, SC, ML, or MH (ASTM D2487) as per the Technical Specifications Sections 02200 and 02235.

# 5.1.4 Performance of the Final Cover System

The final cover system design as proposed conforms to the requirements in the CCR rule at 40 CFR 257.102(d)(3)(i) as follows:

- (A) The permeability of the final cover system is less than or equal to the permeability of the bottom liner system due to the combination of an LLDPE geomembrane, geocomposite drainage layer, 24-inch soil layer, and slopes ranging from 2% minimum to 33% maximum.
- (B) The 18-inch protective cover layer soil meets the requirements for the 18-inch layer of earthen material noted as the *infiltration layer*.
- (C) The 6-inch vegetative support soil layer meets the requirements for the 6-inch layer of earthen material capable of sustaining native plant growth noted as the *erosion layer*.

The integrity of the final cover system is minimized through the use of flexible design components that are well suited to accommodate small changes over time due to settlement and subsidence.

The 24-inch thickness of the final cover system soils is sufficiently thick to protect the underlying geosynthetics from freezing. The maximum expected frost depth for the York County, Virginia area is 18 inches; therefore, the thickness of the soil layer is adequate to protect against freeze/thaw effects.

The Revised Universal Soil Loss Equation (RUSLE) calculations performed for the revised grading demonstrate that the anticipated soil loss is less than 0.2 tons/acre/year, which is less than the standard of 2.0 tons/acre/year. This calculation is presented in Attachment 4.

The final seeding mixture will be applied in accordance with Section 02936 of the Technical Specifications immediately following the placement of the vegetative support layer soil to the design grades. The soil will be seeded with the mix as presented in the Technical Specifications, or with a site-specific mix based on soil testing. While vegetation is being established, soil stabilization matting or other approved erosion control materials will be used to protect the bare soil surface and foster vegetative growth.

# 5.2 Final Slopes

The maximum final slope for the landfill is 3H:1V (18.4%). The minimum final slope per the landfill's permit is 2% to prevent ponding of water. Storm water diversion berms are located at approximately the midpoint of the crown and at the grade break above the steeper side slopes to intercept and collect sheet flow runoff before it concentrates into erosive concentrated flow.

Calculations from the permit design (Golder, 2008) show that the 3:1 final slope is stable under static conditions. A seismic analysis was not performed as the landfill is not located in a seismic impact zone.

# 5.3 Run-Off Controls

Sheet flow from the final cover surface will be collected in a perimeter berm and diverted into downchutes that lead into the perimeter channels. These channels are formed of soil and are sized to convey the runoff from at least the 25-year, 24-hour storm event. The storm water channels are lined with a non-biodegradable erosion control matting to resist erosion and enhance vegetative growth. The average longitudinal slope of the storm water diversion channels is 1.0%.

The perimeter channels drain to the existing stormwater ponds for attenuation and eventual discharge through the VPDES-permitted outfalls 003 and 004. Due to the revised grading plan, a new set of calculations for the stormwater control system and the stormwater ponds are included in Attachment 2 to this Plan. The net effect of the revised landfill grading is an overall reduction in the rate of peak discharge resulting from the flatter top slopes having lower surface water flow velocities and a longer time of concentration.

# 5.4 Settlement, Subsidence and Displacement

It is anticipated that the great majority of foundation settlement to be experienced by the landfill has already occurred, as the landfill has been in operation for approximately 30 years. When CCRs are placed and compacted in a bulk fill, such as a landfill, the material consolidates very rapidly and does not experience further secondary consolidation. Once CCRs are placed, secondary consolidation is negligible. In addition, the landfill is being closed at less than the original design height, resulting in lower than anticipated foundation loading.

Calculations from the permit design (Golder, 2008) show the post-closure settlement of the landfill is anticipated to have a minimal impact on the ability of the cover to prevent infiltration. Localized settlement of the final cover is not anticipated to occur as the CCRs do not decompose and leave voids. Global settlement of the landfill, however small, will cause the liner material to shorten, rather than stretch. Small compressive forces would not affect the integrity or performance of the liner.

# 6.0 CLOSURE OF STORAGE AND/OR TREATMENT UNITS

The Yorktown Power Station does not operate a waste treatment unit at the landfill.

# 7.0 SCHEDULE FOR CLOSURE

The landfill will receive its last waste immediately following the shutdown of the Station's coal fired generating units. After shutdown, remaining CCRs will be removed from the Station and placed in the landfill. Table 1 outlines the anticipated sequence of closure schedule activities.

TABLE 1
CLOSURE SCHEDULE

Activity	Tentative Date
Phase A closure construction complete	November 2017
Yorktown Station cease coal operations	December 2019
Final CCR placed in landfill	By March 2020
Commence Phase B closure construction	March 2020
Phase B closure construction complete	October 2020
Certification of closure	November 2020

# 8.0 CLOSURE IMPLEMENTATION

# 8.1 Closure Posting

One sign will be posted at the site entrance to the landfill notifying all persons of the final closure of the landfill and prohibition against further receipt of CCRs. Unauthorized access to the site will be controlled by fencing (as needed) and lockable gates across the access roads.

# 8.2 Notification

York County, Virginia will be notified upon the completion of closure of the landfill. The closure notification will also be sent to the DEQ, posted on a publicly accessible internet site, and placed in the facility's operating record as outlined in the Final CCR Rule.

The survey plat will be prepared showing the final closure grades and the locations of the groundwater monitoring wells. The survey plat and deed will have the following notification language:

This property has been used for the management and disposal of CCRs. Any future use of the site shall not disturb the integrity of the final cover, liners, or any other components of the containment systems, or the function of the monitoring system unless necessary to comply with the Virginia Solid Waste Management Regulations and the Final CCR Rule or approved by the Department of Environmental Quality.

Within 30 days of recording a notation on the deed to the property, a notification indicating the notation has been recorded will sent to DEQ, posted on a publicly accessible internet site, and placed in the facility's operating record.

# 8.3 Certification

Upon completion of closure construction, a certification statement, signed by a licensed professional engineer, will be submitted to the DEQ along with the results of the CQA plan. The certification statement shall read as follows:

I certify that closure has been completed in accordance with the Closure Plan dated [DATE] for solid waste permit number 457 issued to Dominion, with the exception of the following discrepancies: [To Be Determined]

In addition, a sign(s) was (were) posted on [DATE] at the landfill entrance notifying all persons of the closing [and state other notification procedures if applicable] and barriers [indicate type] were installed at [location] to prevent new waste from being deposited.

A survey plat prepared by [NAME] was submitted to York County, Virginia on [DATE]. A copy of the survey plat is included with this certification.

A notation was recorded on the deed to the landfill property on [DATE]. A copy of the revised deed is attached to this certification.

[Signature, date and stamp of Professional Engineer]

# 9.0 CLOSURE COST ESTIMATE

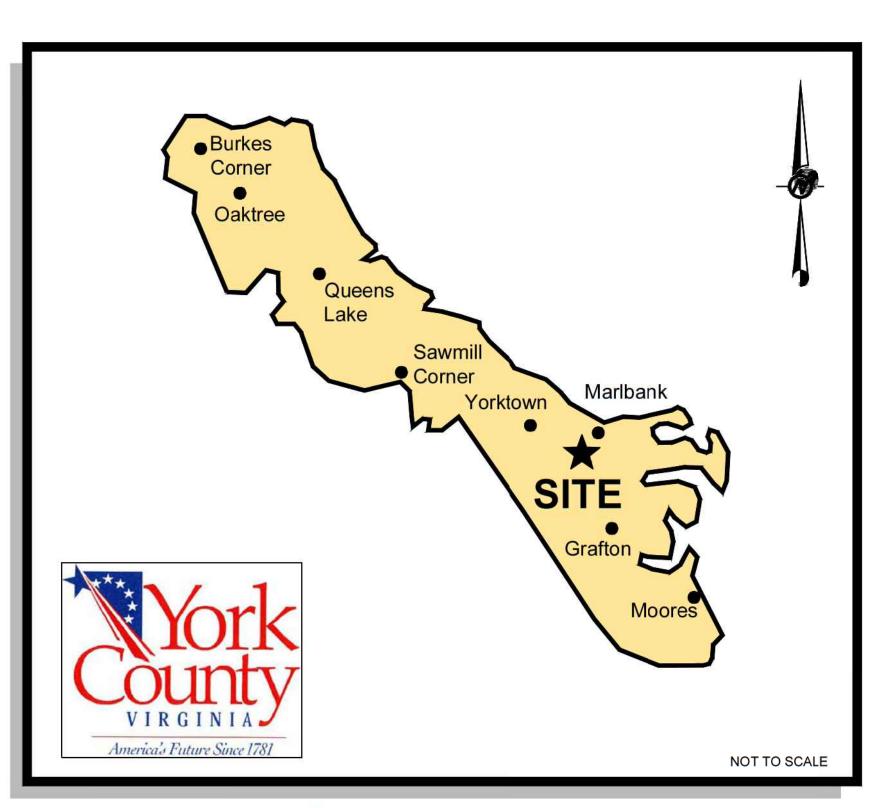
The estimated cost for closure of Phase B (19.2 acres) of the landfill is \$5,000,000. Dominion will hire a construction contractor to provide closure construction services. Calculations for the closure cost estimate are included in Attachment 8.

# Attachment 2

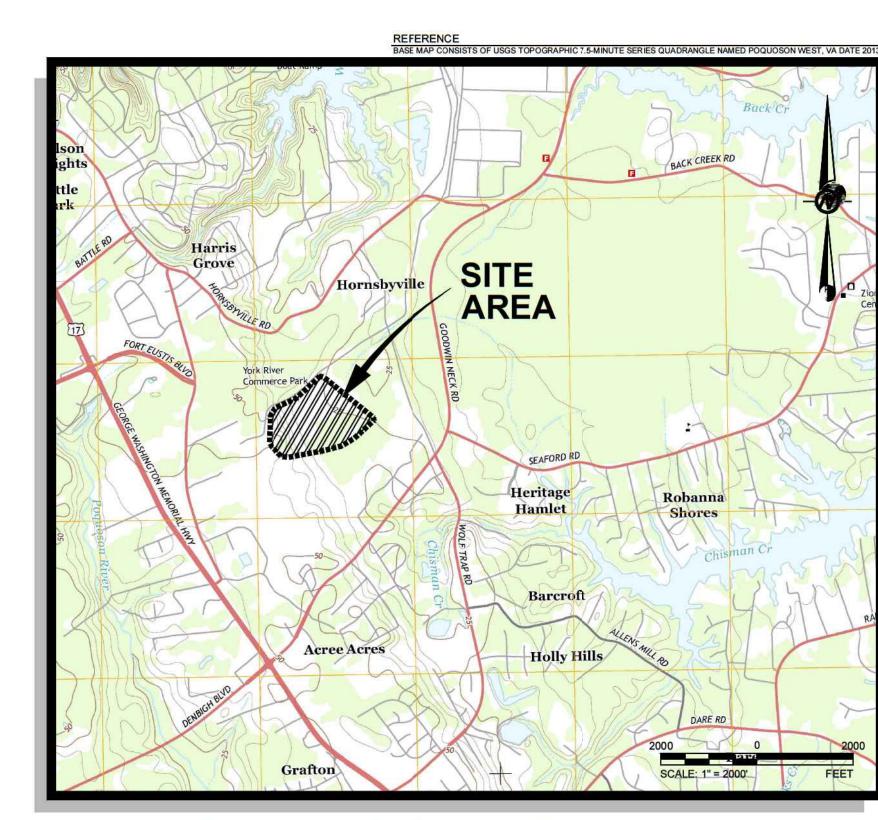
**Closure Design Plans and Calculations** 

# DOMINION YORKTOWN POWER STATION LANDFILL CLOSURE PLAN AMENDMENT SOLID WASTE PERMIT #457

YORK COUNTY, VIRGINIA NOVEMBER, 2015



SHEET LIST TABLE		
Sheet Number	Sheet Title	
1	COVER SHEET	
2	EXISTING CONDITIONS	
3	PHASE A LINER GRADES	
4	PHASE A FINISH GRADES	
5	PHASE A CROSS SECTIONS	
6	PHASE A STORMWATER MANAGEMENT PLAN	
7	PHASE B LINER GRADES	
8	PHASE B FINISH GRADES	
9	PHASE B CROSS SECTIONS	
10	PHASE B FINAL STORMWATER MANAGEMENT PLAN	
11	STORMWATER DETAILS	
12	LINER DETAILS	
13	EROSION AND SEDIMENT CONTROL NOTES AND DETAILS	



SITE LOCATION MAP

# **VICINITY MAP**

# **CONTACT INFORMATION**

# PREPARED BY:



ENGINEER:
GOLDER ASSOCIATES INC.
MAIN CONTACT: DANIEL McGRATH, P.E.
2108 W. LABURNUM AVE., SUITE 200
RICHMOND, VIRGINIA 23227
PHONE: (804) 358-7900
FAX: (804) 358-2900
EMAIL: DANIEL\_McGRATH@GOLDER.COM

OWNER / DEVELOPER:
DOMINION - YORKTOWN POWER STATION
MAIN CONTACT: WARREN DEAL
1600 WATERVIEW ROAD
YORKTOWN, VA 23960
PHONE: (757) 898-2771

PREPARED FOR:



|--|

REV DATE DES REVISION DESCRIPTION CADD CHK						RVW	
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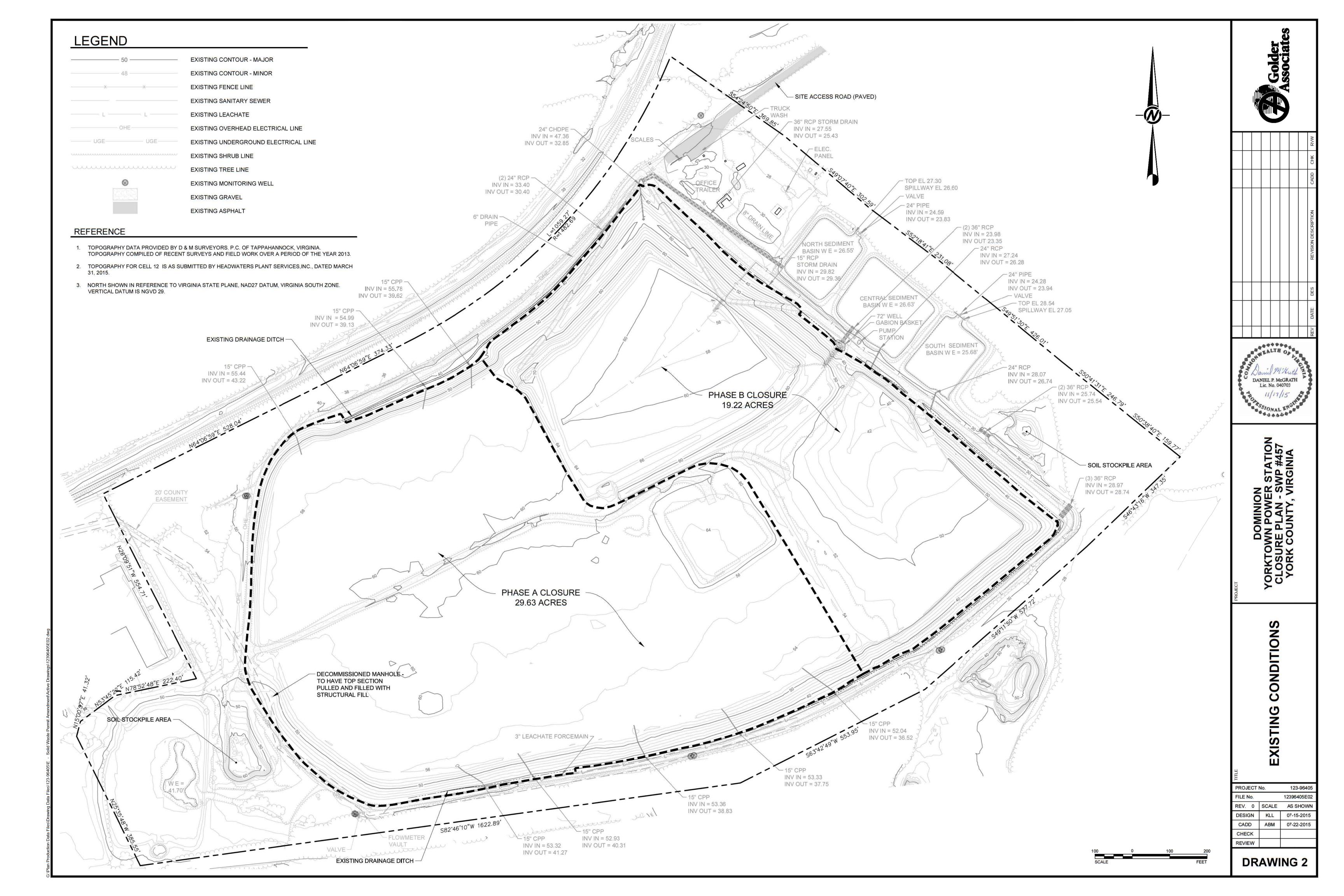
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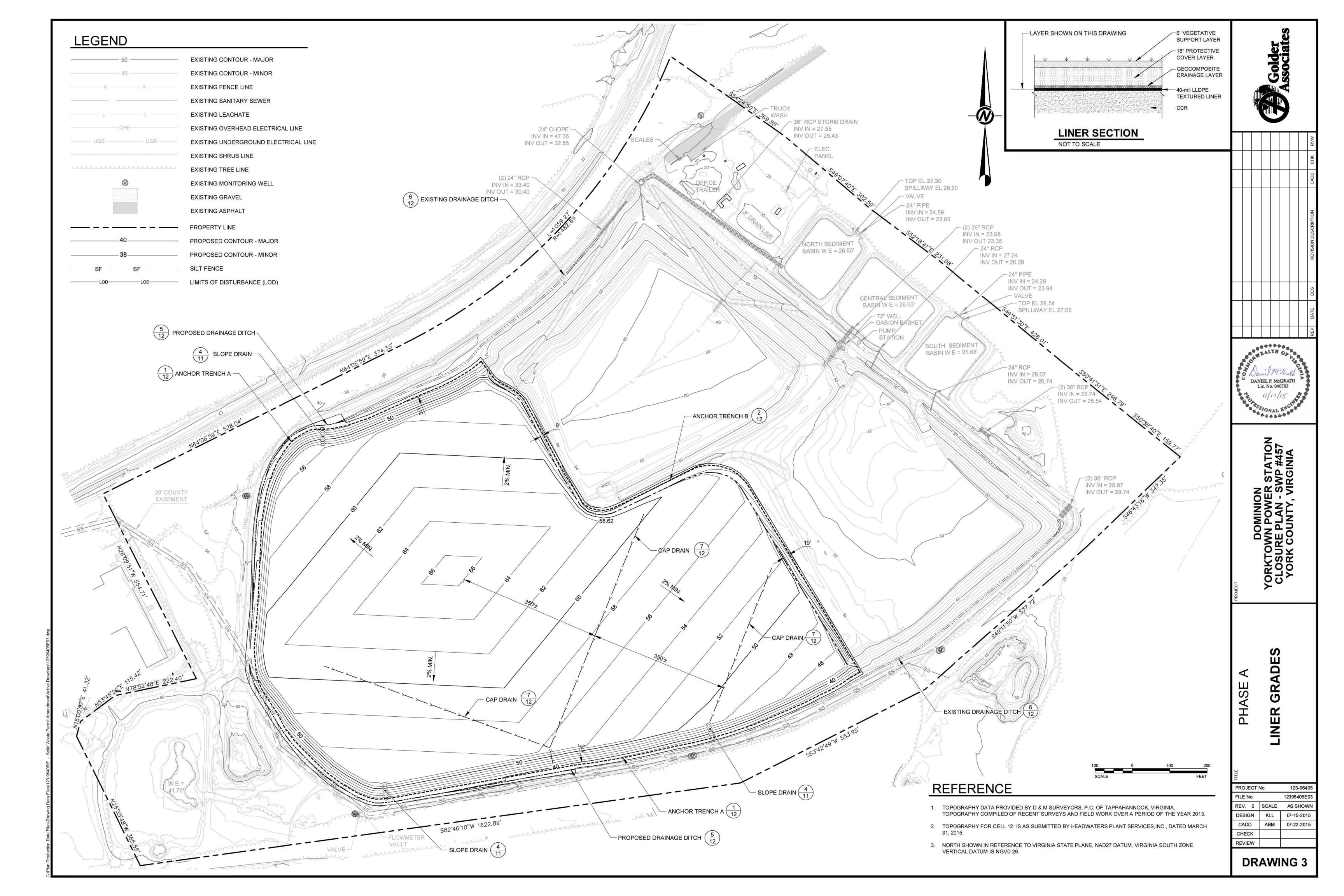
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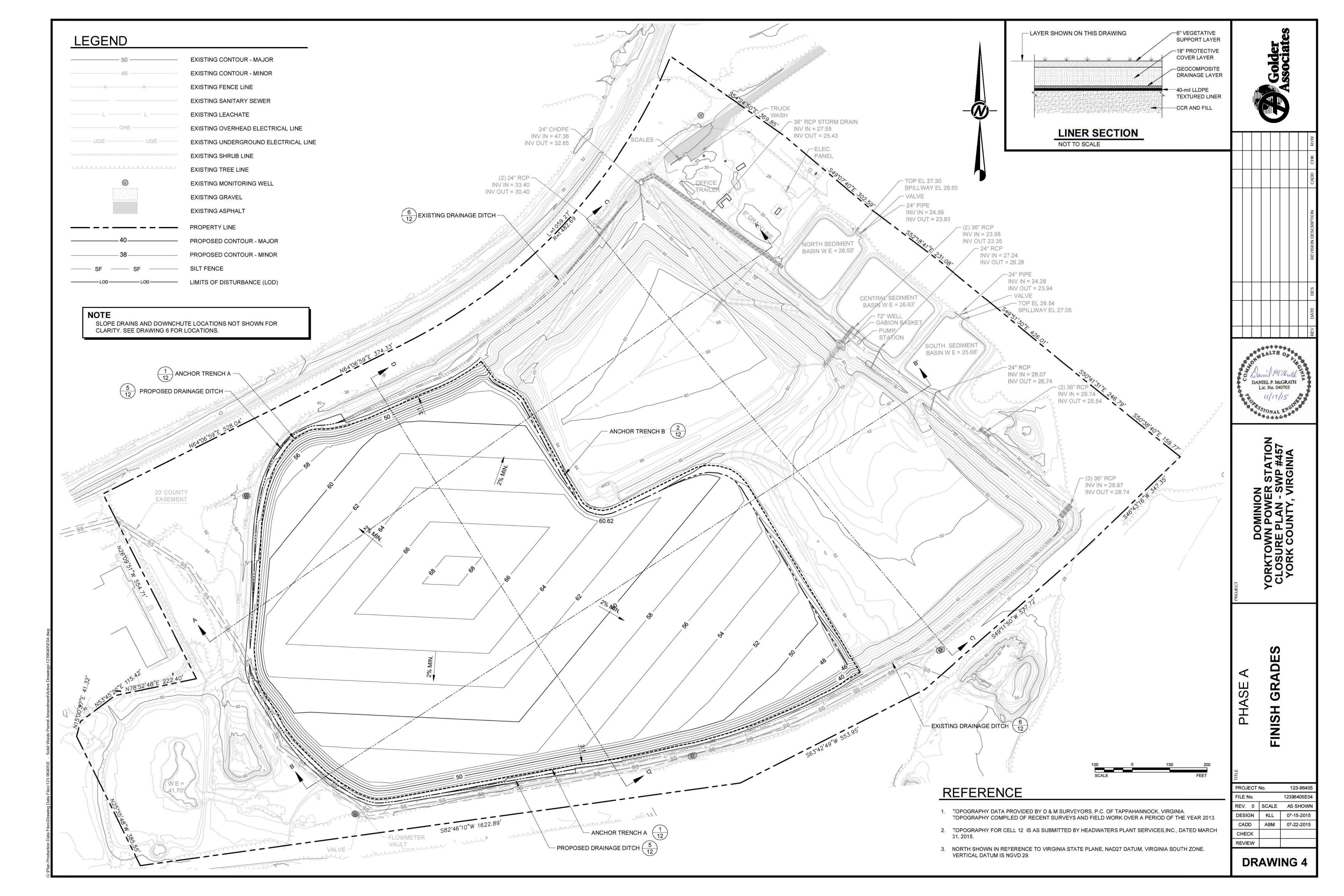
CLOSURE PLAN - SWP #457

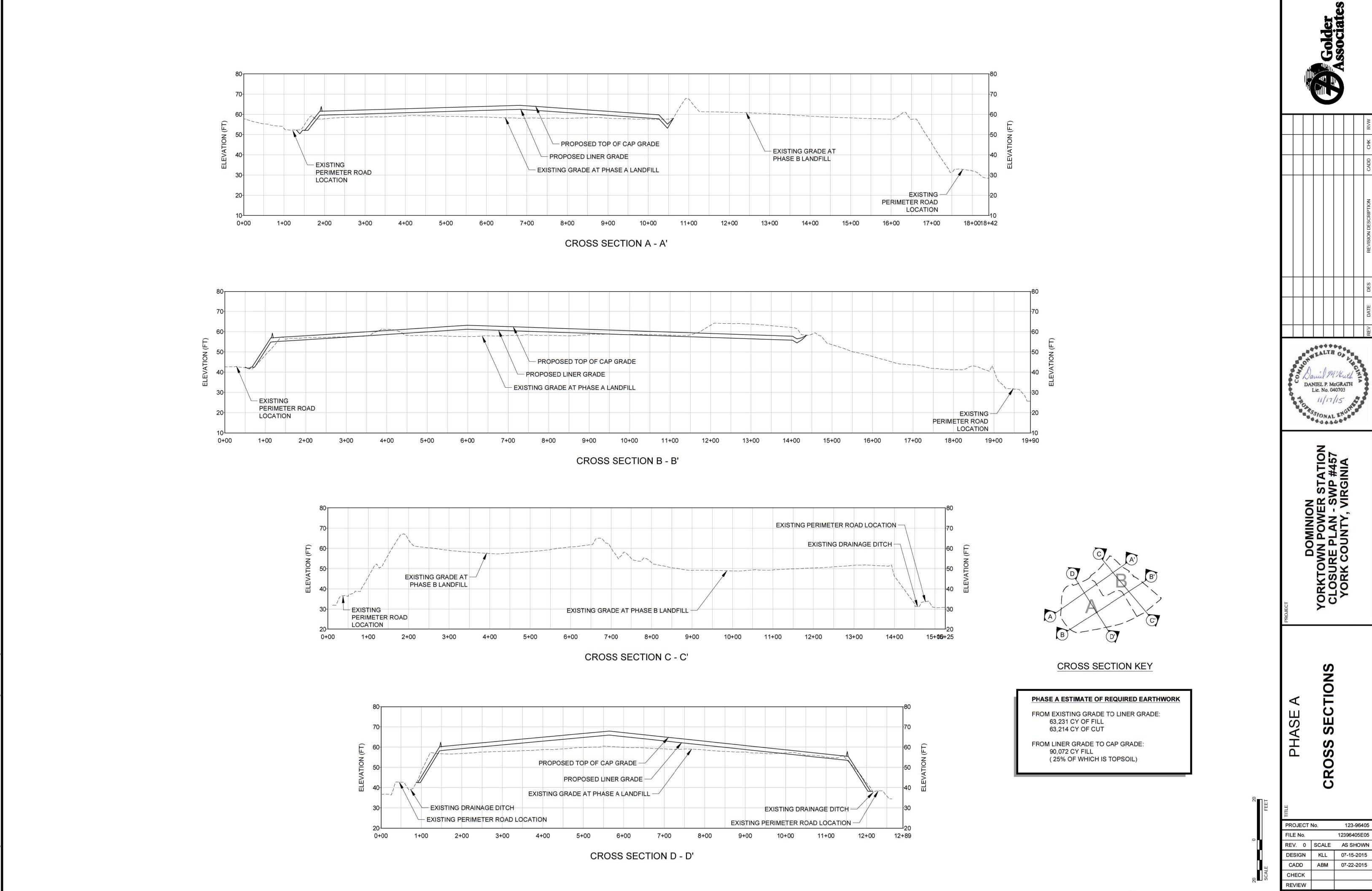
COVER SHEET

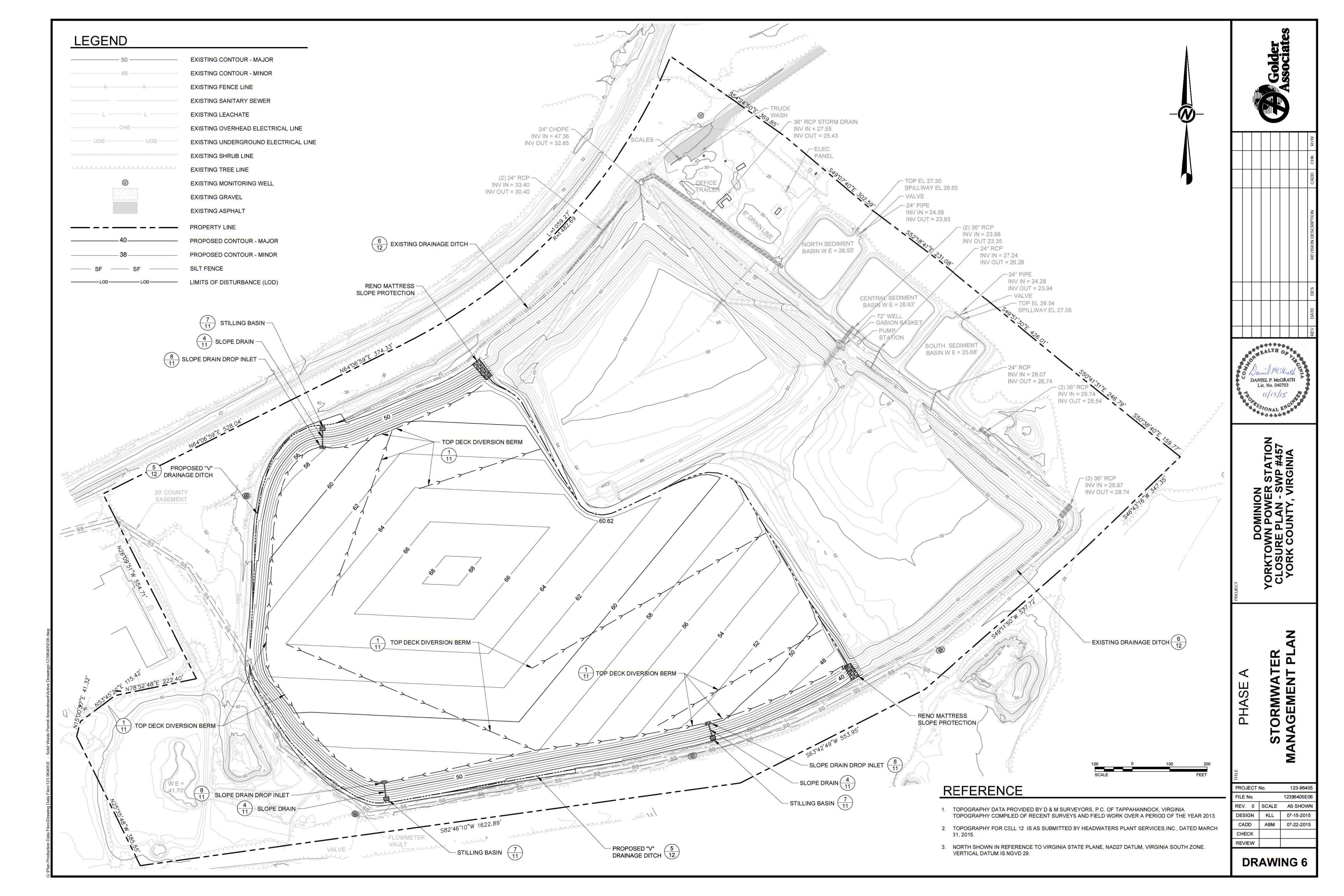
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ABM	07-22-2015
	SCALE KLL

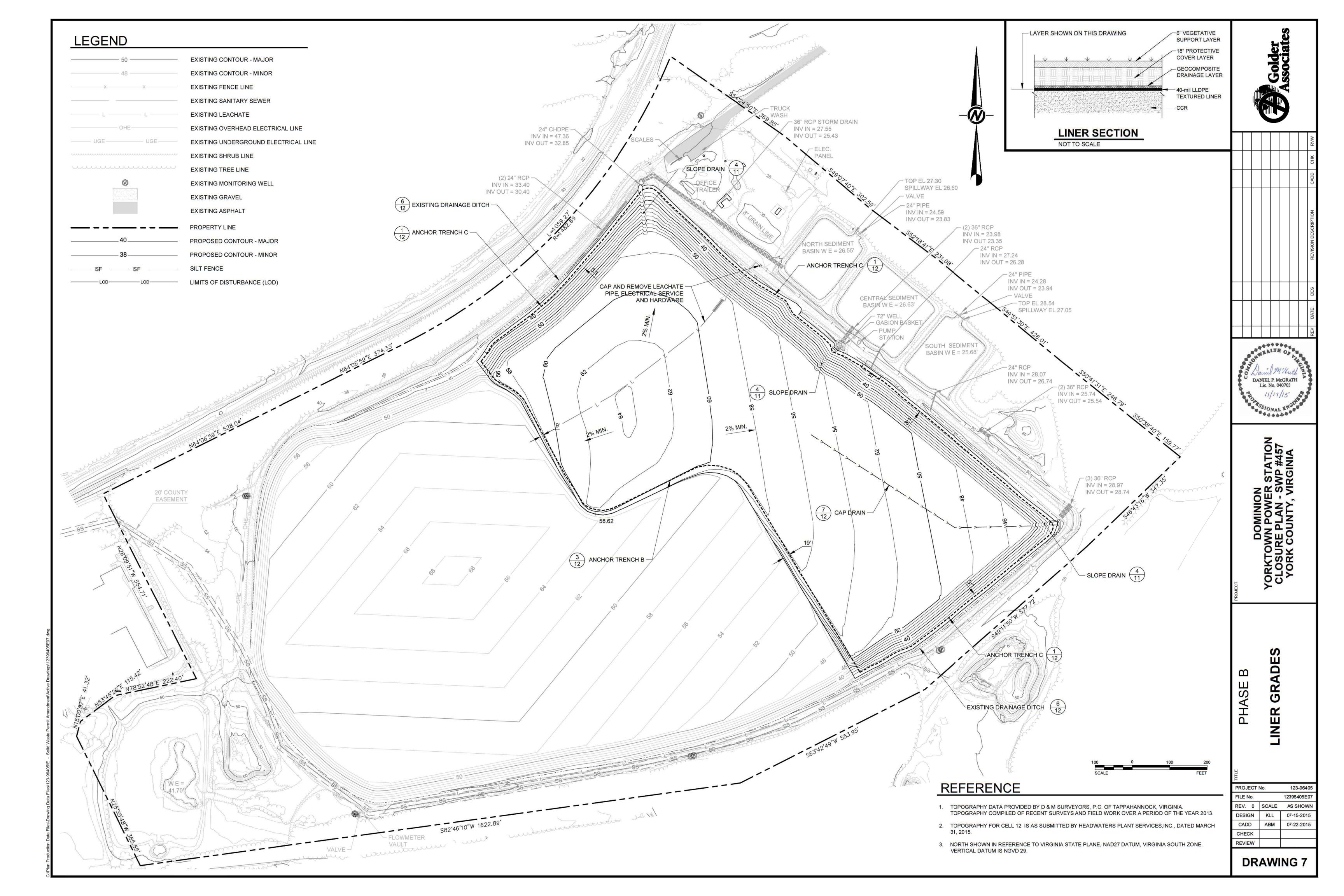


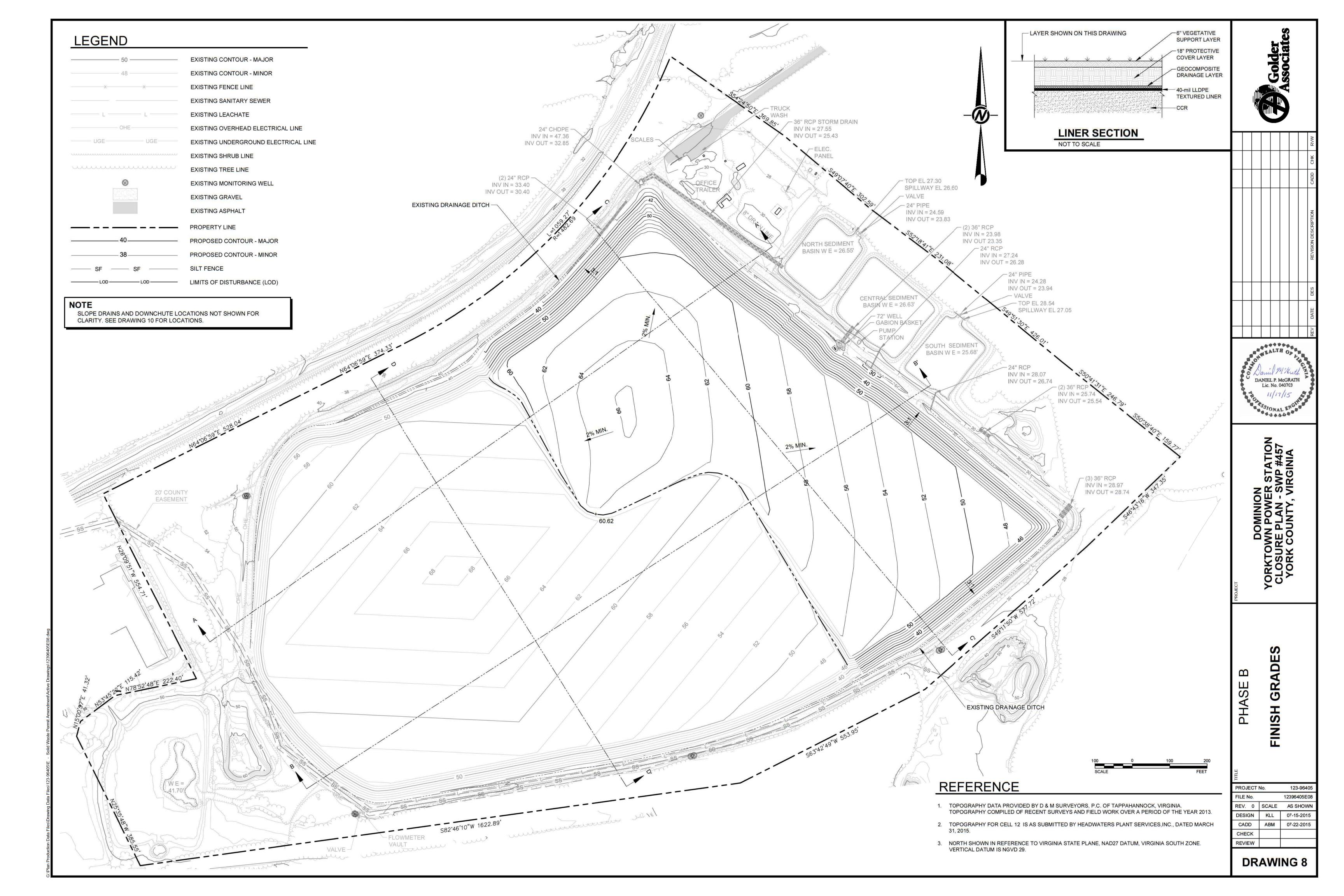


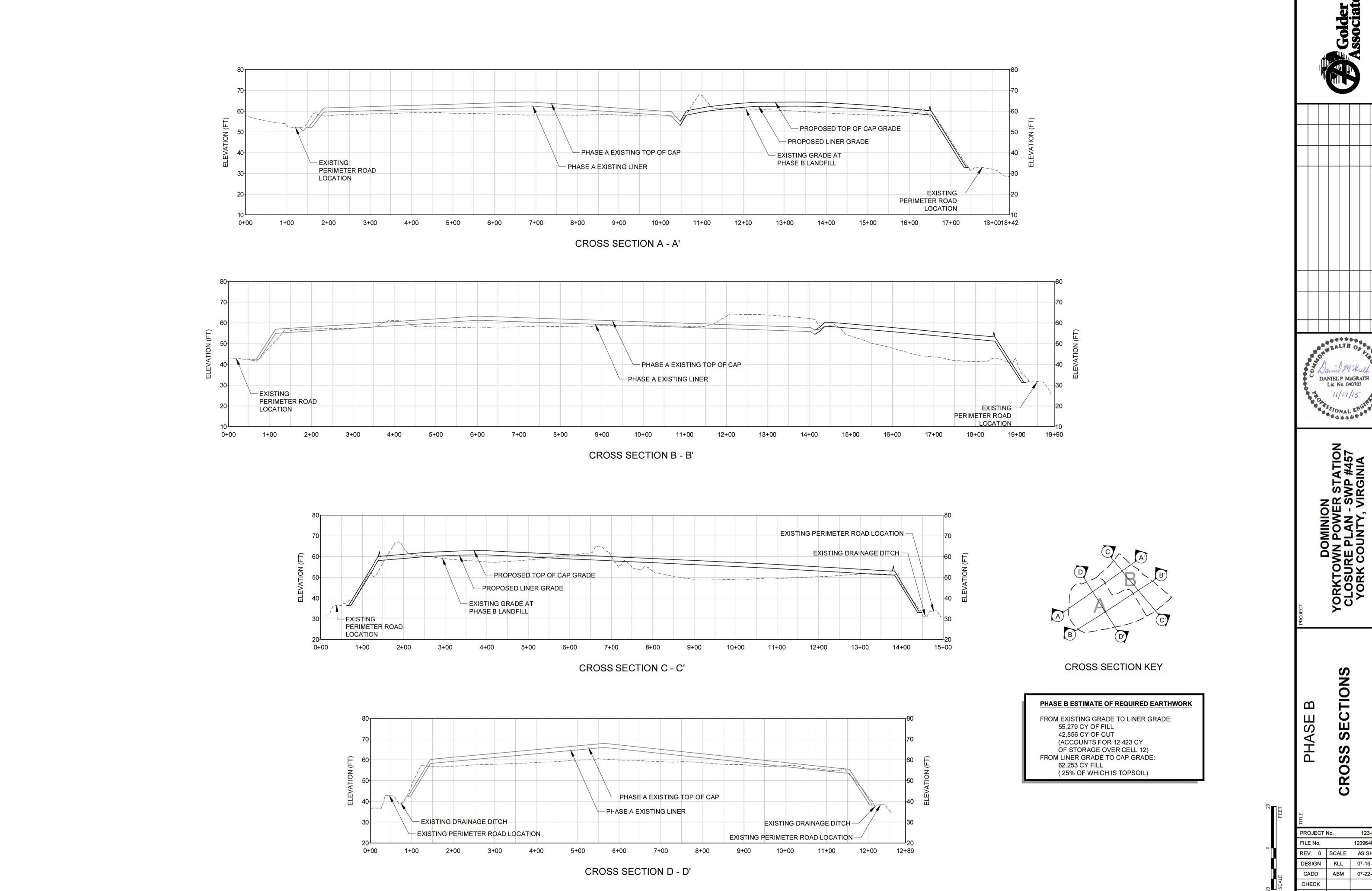




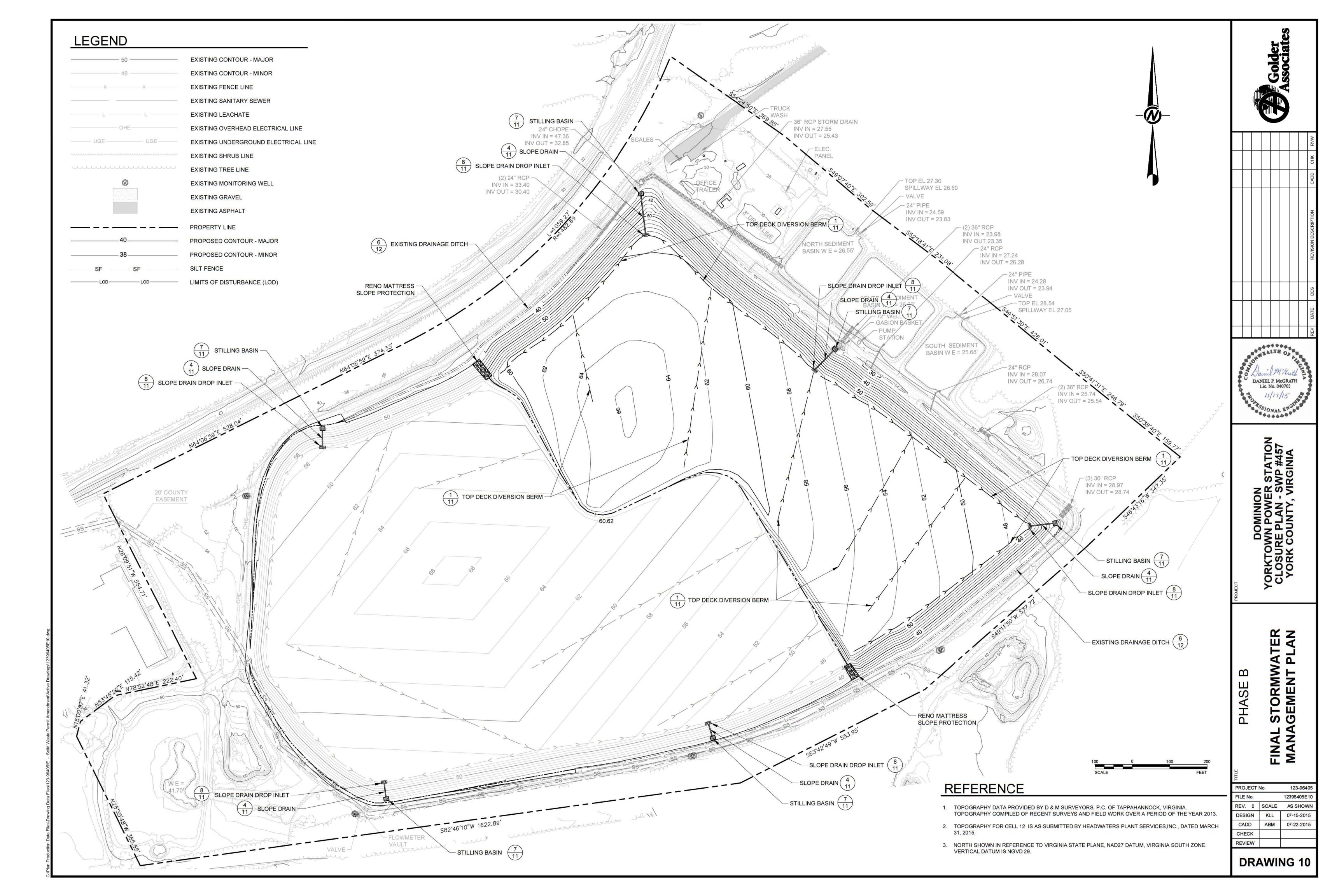


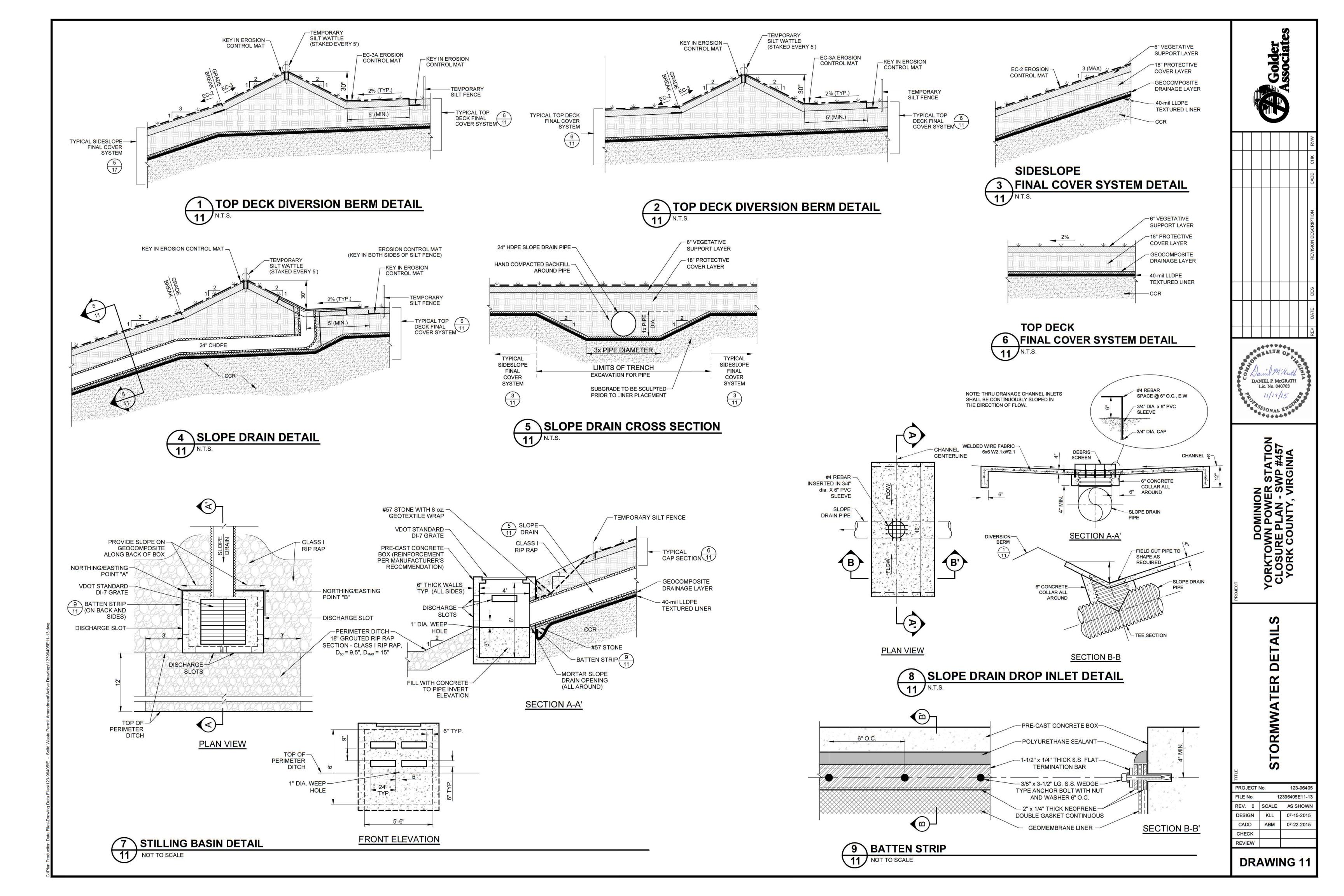


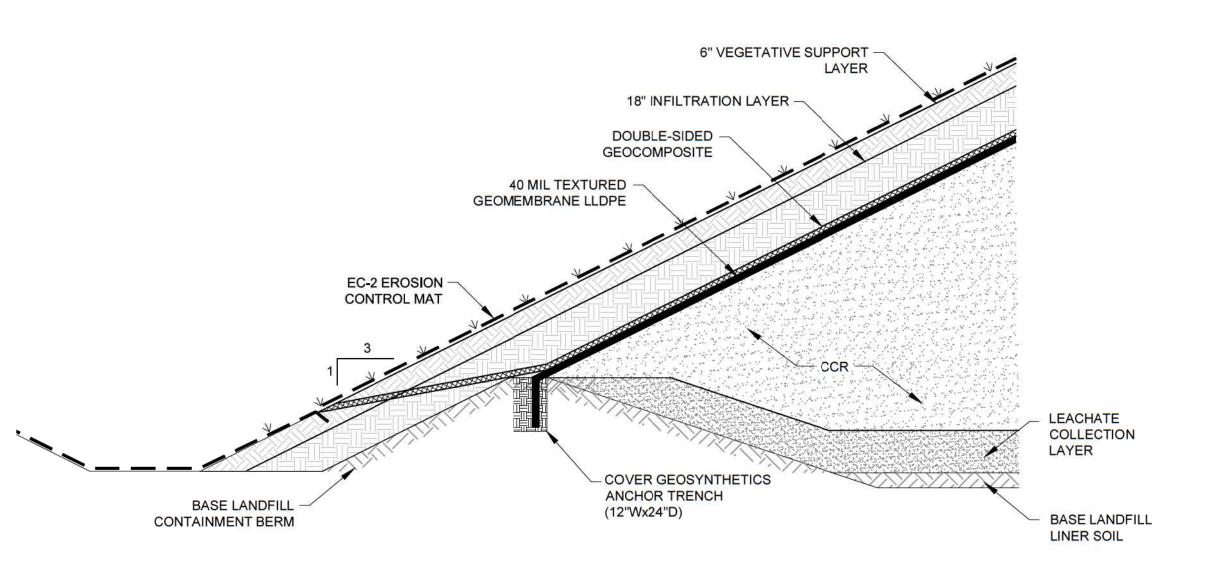


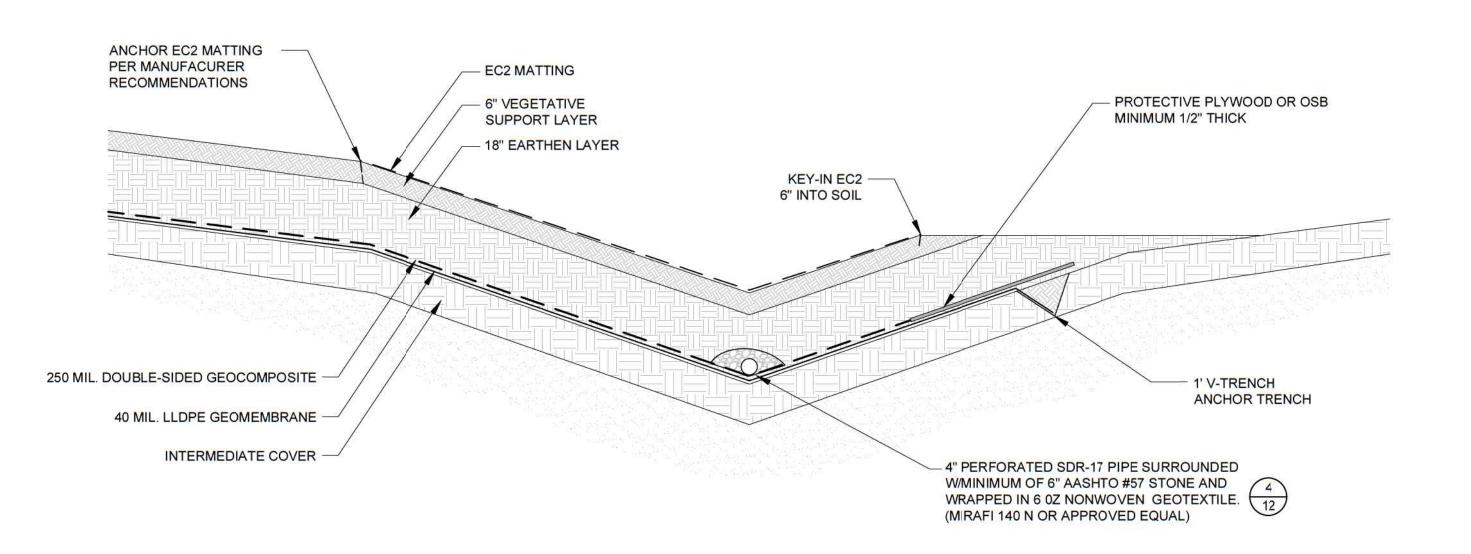


123-96405 12396405E09 REV. 0 SCALE AS SHOWN DESIGN KLL 07-15-2015 07-22-2015 REVIEW



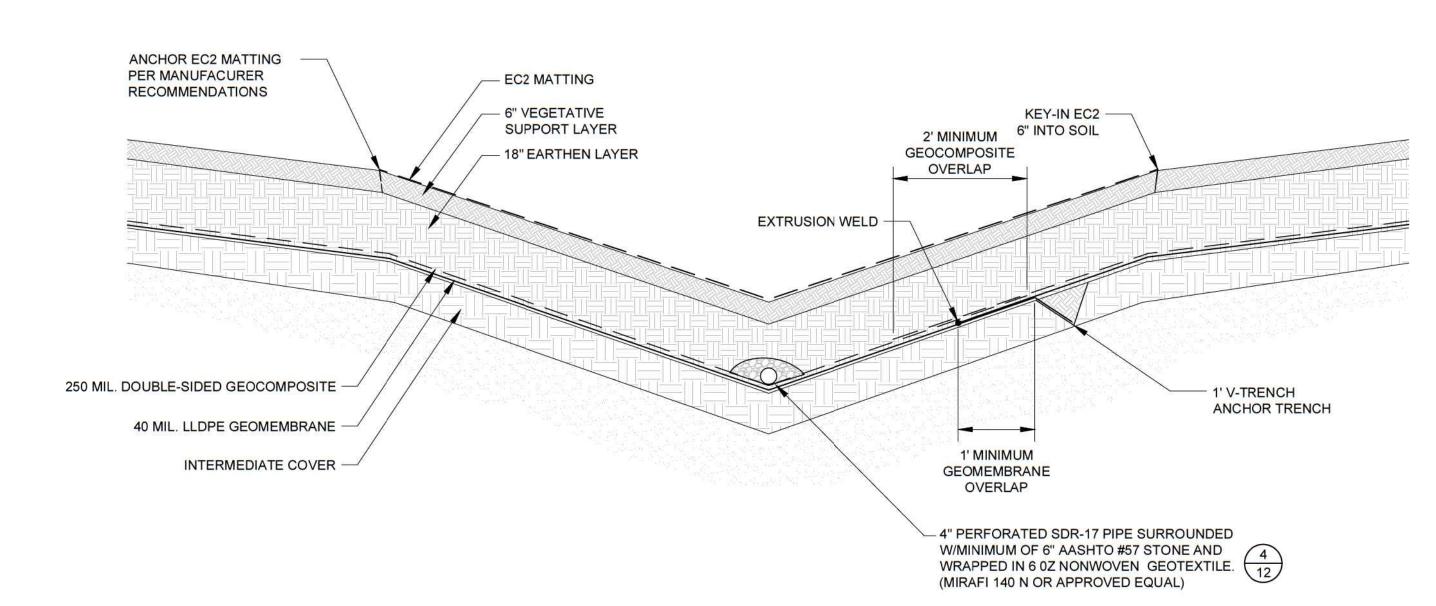


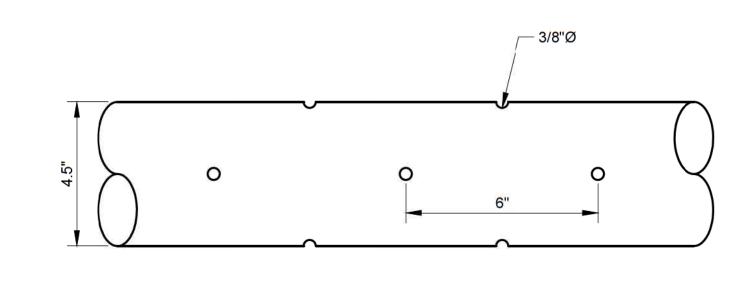




1 ANCHOR TRENCH A & C
12 N.T.S.

2 ANCHOR TRENCH B - PHASE A
12 NOTTO SCALE





4" HDPE SDR-17 PIPE 12 N.T.S.

# 3 ANCHOR TRENCH B - PHASE B NOT TO SCALE

2% MIN\_

VDOT #57 STONE — OR COARSE SAND

4" PERFORATED SDR-17 PIPE SURROUNDED W/MINIMUM OF 6" AASHTO

NONWOVEN GEOTEXTILE. (MIRAFI 140 N OR APPROVED EQUAL)

#57 STONE AND WRAPPED IN 6 0Z

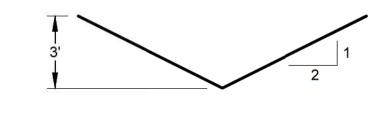
— 4' WIDE STRIP OF

GEOCOMPOSITE

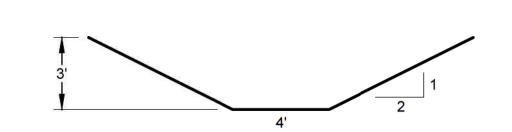
NONWOVEN GEOTEXTILE HEAT SEAMED TO TOP OF

2% MIN

24" SOIL COVER









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DANIEL P. McGRATH Lic. No. 040703

**DRAWING 12** 

ABM

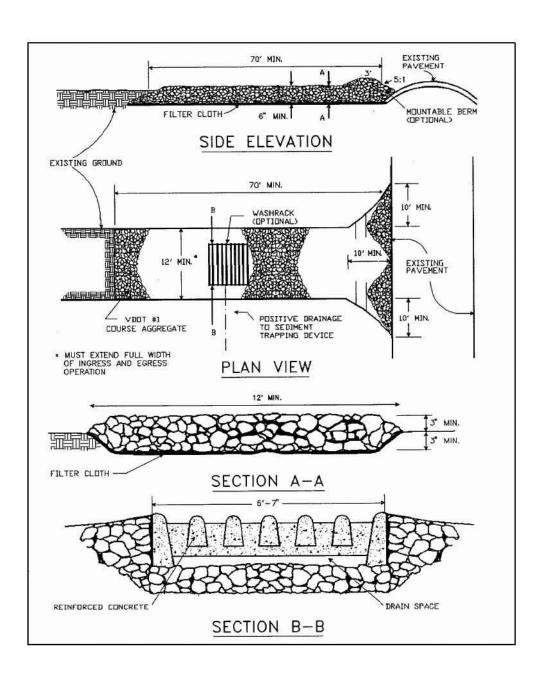
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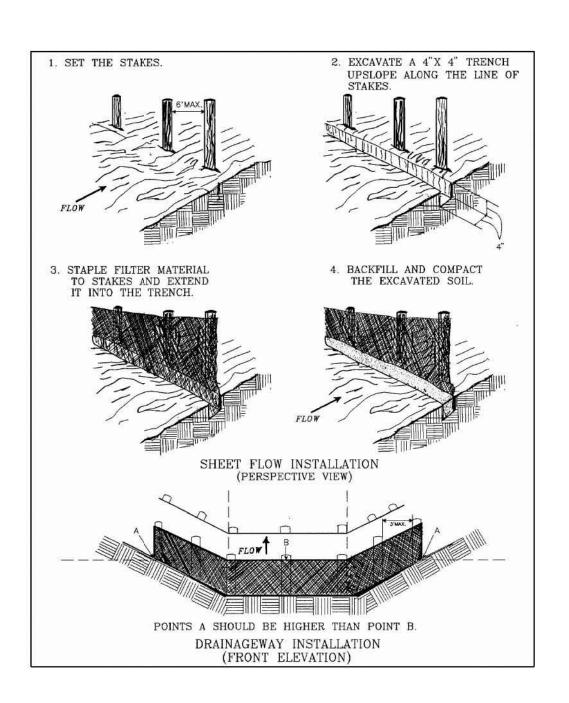
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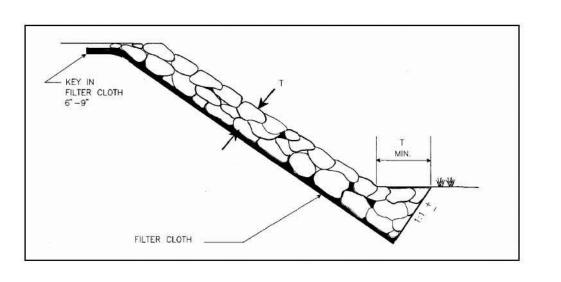
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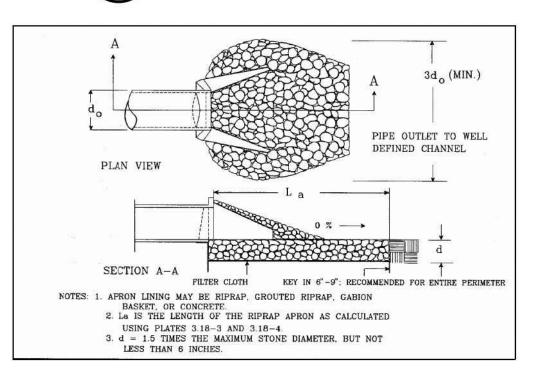
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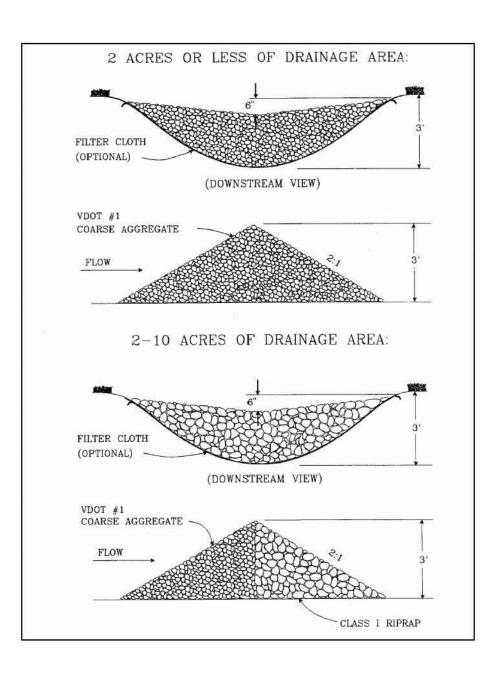


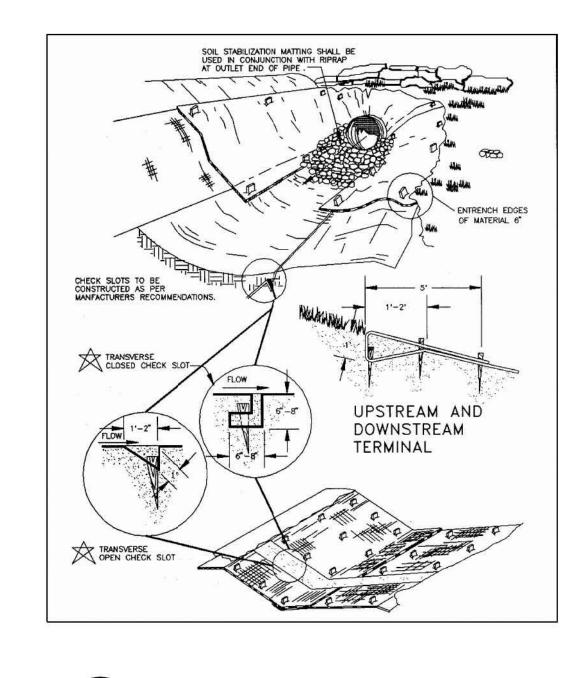


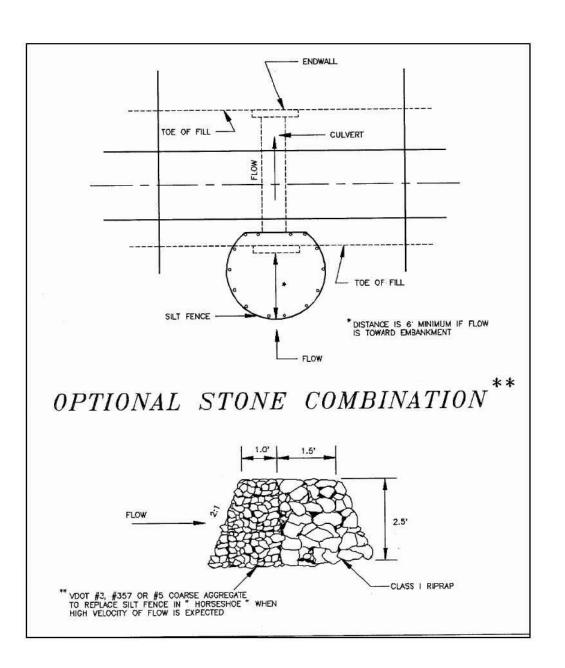








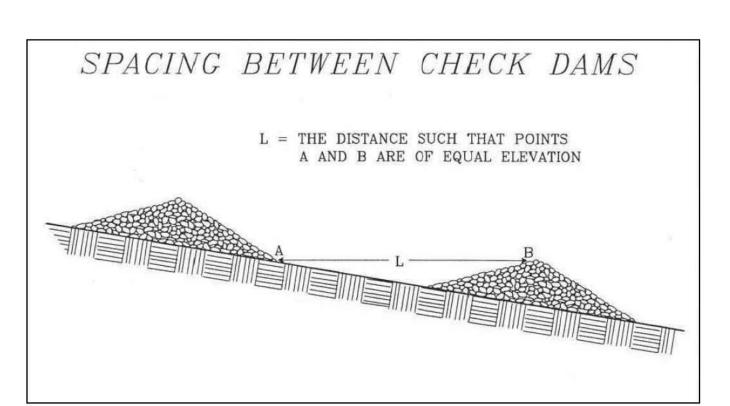














# **TEMPORARY SEEDING NOTES**

- 1. ALL TEMPORARY SEEDING, FERTILIZING AND LIMING SHALL BE DONE IN ACCORDANCE WITH SPECIFICATION 3.31 OF THE VIRGINIA EROSION AND SEDIMENT CONTROL HANDBOOK (VESCH), THIRD EDITION, 1992. MULCHING SHALL BE DONE IN ACCORDANCE WITH SPECIFICATION 3.35 OF THE VESCH.
- TEMPORARY SEEDING WILL BE APPLIED WITHIN 7 DAYS TO DENUDED AREAS WHICH MAY NOT BE AT FINAL GRADE BUT WILL REMAIN DORMANT (UNDISTURBED) FOR LONGER THAN 30 DAYS. FOR TEMPORARY SEEDING USE 50% OF THE RECOMMENDED RATES OF FERTILIZER AND LIME, AND FULL RATES OF SEED AND MULCH, AS SPECIFIED IN THE VESCH STANDARD FOR PERMANENT SEEDING.
- 3. ALL SOIL STOCKPILES ARE TO BE MULCHED AND SEEDED FOR VEGETATIVE COVER IMMEDIATELY AFTER GRADING. STRAW OR HAY MULCH IS REQUIRED.

TEMPORARY SEEDING MIXTURES FOR ALL AREAS: RATE (LBS/AC.) PLANTING DATES SPECIES **SEPT 1 - FEB 15** 50/50 MIX OF ANNUAL RYE & 50-100

**CEREAL WINTER RYE** ANNUAL RYE 60-100 FEB 16 - APR 30 MAY 1 - AUG 31 GERMAN MILLET 50-100

# PERMANENT SEEDING NOTES

- 1. ALL SEEDING, FERTILIZING AND LIMING SHALL BE DONE IN ACCORDANCE WITH SPECIFICATION 3.32 OF THE VESCH. MULCHING SHALL BE DONE IN ACCORDANCE WITH SPECIFICATION 3.35 OF THE VESCH.
- 2. CONDUCT SOIL TESTING PRIOR TO SEEDING. THE AREA TO BE SEEDED SHALL FIRST BE FERTILIZED AND TREATED WITH AGRICULTURAL LIME IN ACCORDANCE WITH THE SOIL TESTING RESULTS. SOIL ADDITIVES SHALL BE WORKED INTO THE SURFACE A MINIMUM DEPTH OF ONE INCH.
- PERMANENT SEEDING SHALL BE DONE ONLY BETWEEN THE DATES OF FEBRUARY 15 AND JUNE 15 OR BETWEEN SEPTEMBER 15 AND DECEMBER 15, EXCEPT AS OTHERWISE DIRECTED BY THE ENGINEER. ABSENT OF SITE-SPECIFIC SOIL TESTING AND SEED MIXTURE RECOMMENDATIONS, FOLLOW THE SEEDING SCHEDULE

SEEDING MIXTURES FOR THE COASTAL PLAIN REGION SPECIES KENTUCKY 31 FESCUE RED TOP GRASS SEASONAL NURSE CROP\* TOTAL: 150 LBS./AC.

\*USE SEASONAL NURSE CROP IN ACCORDANCE WITH SEEDING DATES AS STATED BELOW:

PLANTING DATES FEBRUARY - APRIL ANNUAL RYE MAY - AUGUST FOXTAIL MILLET SEPTEMBER - NOVEMBER 15 ANNUAL RYE **NOVEMBER 15 - JANUARY** WINTER RYE

- 4. AFTER SEEDING, THE SURFACE SHALL BE COVERED WITH STRAW OR HAY AT THE RATE OF 70-90 LBS PER 1,000 SQ. FT.
- LIME AND FERTILIZER SCHEDULE:

2 TON/ACRE PULVERIZED AGRICULTURAL GRADE LIMESTONE (MAXIMUM 100 LBS/1,000 SQ. FT.)

1000 LBS/ACRE 12-12-12 OR EQUIVALENT NUTRIENTS, (23 LBS/1,000 SQ. FT.)

# PHASE 1 EROSION AND SEDIMENT CONTROL SEQUENCE

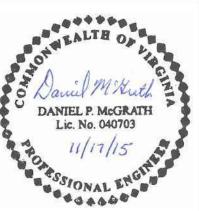
- 1. ALL PHASE 1 EROSION AND SEDIMENT CONTROLS SHALL BE INSTALLED AT THE LOCATIONS SHOWN ON THE DRAWINGS. CONTROLS SHALL MEET MINIMUM STANDARDS AND SPECIFICATIONS FROM THE VIRGINIA EROSION AND SEDIMENT CONTROL HANDBOOK (VESCH).
- 2. PHASE 1 EROSION AND SEDIMENT CONTROLS ARE TO BE INSTALLED AS THE FIRST STEP IN CONSTRUCTION. NO LAND DISTURBING ACTIVITIES ARE TO TAKE PLACE PRIOR TO INSTALLATION OF ALL CONTROLS SHOWN ON THE DRAWINGS.
- 3. CONTACT YORK COUNTY NO LATER THAN FORTY-EIGHT (48) HOURS PRIOR TO LAND DISTURBING ACTIVITIES SO A PRE- CONSTRUCTION MEETING AND INSPECTION CAN BE SCHEDULED.
- 4. INSTALL CONSTRUCTION ENTRANCE.
- 5. INSTALL CULVERT INLET PROTECTION ON EXISTING CULVERTS
- INSTALL SILT FENCE.
- 7. ONCE ALL CONTROLS LISTED ABOVE HAVE BEEN INSTALLED, COMMENCE WITH RESHAPING AND GRADING OF LANDFILL.
- 8. TEMPORARY SEEDING SHALL BE APPLIED WITHIN 7 DAYS TO DENUDED AREAS WHICH MAY NOT BE AT FINAL GRADE BUT WILL REMAIN DORMANT (UNDISTURBED) FOR LONGER THAN 30 DAYS. SEE TEMPORARY SEEDING NOTES ABOVE FOR SPECIFICATIONS.
- 9. WHENEVER SEDIMENT-LADEN WATER IS REMOVED FROM A CONSTRUCTION SITE BY MEANS OF PUMPING, A TEMPORARY SETTLING & FILTERING DEVICE SHALL BE USED TO FILTER THE SEDIMENT-LADEN WATER PRIOR OT THE WATER BEING DISCHARGED FROM THE SITE.

# PHASE 2 EROSION AND SEDIMENT CONTROL SEQUENCE

- 1. ALL PHASE 2 EROSION AND SEDIMENT CONTROLS SHALL BE INSTALLED AT THE LOCATIONS SHOWN ON DRAWINGS. CONTROLS SHALL MEET MINIMUM STANDARDS AND SPECIFICATIONS FROM THE VESCH.
- GRADE LANDFILL TO LINER GRADES.
- INSTALL LINER.
- 4. GRADE LANDFILL TO FINISH CAP GRADES. TOPSOIL SEED AND MULCH.
- INSTALL PERMANENT SEEDING AS AREAS ARE BROUGHT TO FINAL GRADE.
- 6. THE CONSTRUCTION ENTRANCE MAY BE REMOVED ONCE CONSTRUCTION ACTIVITIES ARE COMPLETE.
- 7. EROSION AND SEDIMENT CONTROL MEASURES MAY ONLY BE REMOVED ONCE ADEQUATE VEGETATION IS ESTABLISHED AND APPROVAL FOR REMOVAL IS GRANTED BY THE EROSION AND SEDIMENT CONTROL
- RIP RAP OUTLET PROTECTION IS TO REMAIN.



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DIMEN S AND SE EROSION AND S CONTROL NO DETAIL

PROJECT No. 123-96405 FILE No. 12396405E11-13 REV. 0 SCALE AS SHOWN DESIGN KLL 07-15-2015 CADD ABM 07-22-2015 CHECK REVIEW



Subject: Hydrologic & system for the	Hydraulic Analysis of the storm e Dominion Yorktown Landfill C	nwater conveyance Closure
Job No. 123-96405	Made By: MAK	Date: 9/1/2015
JOD NO. 123-96405	Checked: DPM	Date. 3/1/2013
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Rev 1		

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of 6

Reviewed: JRD

### **OBJECTIVE**

The objective of this analysis is to evaluate the stormwater components of the closure cap system for capacity to adequately convey the 10-year and 25-year storm events. The components designed under this set of engineering calculations include sideslope berms, downslope pipes, perimeter channels and an evaluation of the modified stormwater basin's performance. The design is to:

- Adequately convey the 10 and 25-year, 24-hour storm to the stormwater basin without overbank conditions in the sidelslope berms and perimeter channels; and,
- Be non-erosive for the 2-year stormwater flow.

# **METHOD**

Evaluation of stormwater runoff will be made using hydraulic modeling software HEC-HMS (ref #1). Determining hydraulic grade line in channels is determined by the Manning equation (by spreadsheet analysis) at various cross sections. Each section evaluates the freeboard to determine adequate conveyance.

Where:

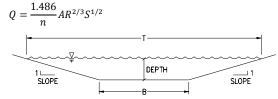
Q= flow in cubic feet per second (cfs)

R = hydraulic radius, feet

A = cross sectional area of flow, ft^2

S = channel slope, ft/ft

n = Manning's coefficient of roughness



- Sideslope berms the berms were designed to ensure at least one-half foot of freeboard during a 25-year storm event and to ensure sufficient capacity during a 100-year storm event.
- Perimeter channels- the perimeter channels were checked to provide freeboard for both the 10-year and 25-year storm event.
- The stormwater basins were checked to verify riser performance and that adequate freeboard remains in the basin under the evaluated design storms.

# **ASSUMPTIONS**

- The surface Runoff Curve Numbers (CN) used in this evaluation were 74 for the finished landfill cover area (HSG-C, grass, good condition) and 77 for areas containing sections of the perimeter access road. A CN of 98 was used for the pond surface. Most, if not all, of the cover soil will be imported to the site from a yet-to-be-determined borrow area.
- 2. The perimeter channels and the sideslope berms have one surface type with a Manning's "n" value of 0.035 (grass-lined).
- 3. The annual 2, 10, 25, and 100-year storm rainfall depths were identified in the Precipitation Frequency Data Server (PFDS Reference 2) for Yorktown, Virginia:

Year	(in) /
Storm	24hrs
2	3.56
10	5.51
25	6.85
100	9.30



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Subject: Hydrologic & Hydraulic Analysis of the stormwater conveyance system for the Dominion Yorktown Landfill Closure					
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# **CALCULATIONS**

# **HMS Model Input**

Sub-area delineations/flow path to point of interest are illustrated on Drawing 1 (attachment 2). Figure 1 illustrates the connectivity of the stormwater elements as modeled in HEC-HMS:

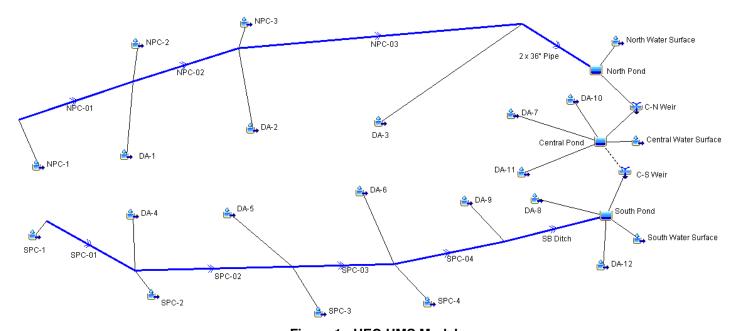


Figure 1 - HEC-HMS Model

**Table 1: HEC-HMS Input Data** 

Element	DA (Ac)	CN	Lag Time (min)
DA-1	2.51	74	6.9
DA-2	7.18	74	12.7
DA-3	3.31	74	8.8
DA-4	2.72	74	6.0
DA-5	4.23	74	10.4
DA-6	11.13	74	13.0
DA-7	2.85	74	8.6
DA-8	2.61	74	6.5
DA-9	3.52	74	6.4
DA-10	1.88	77	6.0
DA-11	0.65	77	6.0
DA-12	1.07	77	6.0
NPC-1	1.01	77	6.0
NPC-2	1.14	77	6.0



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NPC-3	1.58	77	6.0
SPC-1	0.97	77	6.0
SPC-2	1.64	77	6.0
SPC-3	0.74	77	6.0
SPC-4	1.54	77	6.0
North Water Surface	0.60	98	1.0
Central Water Surface	0.92	98	1.0
South Water Surface	0.59	98	1.0
Stormwater Basin in (3 Total)	52.28		

# Individual Areas for Component Evaluation:

Rev 1

Largest Inlet	4.23	74	10.4
Next Largest Inlet	4.23	74	6.4
Largest Bench	4.58	74	13.0

In addition to evaluating the stormwater system as a whole, individual, unconnected components were established in the model to evaluate specific inlets or sideslope berms. The modeled flows for the individual components were used in further spreadsheet analysis to determine capacities and freeboard.

# **HMS Model Output**

The following table summarizes the results of the HEC-HMS analysis for given storms.

**Table 2: HEC-HMS Output** 

Drainage Areas	DA (Ac)	Q <sub>2</sub> (CFS)	Q <sub>10</sub> (CFS)	Q <sub>25</sub> (CFS)	Q <sub>100</sub> (CFS)
DA-1	2.51	4.5	9.8	13.8	21.3
DA-2	7.18	9.9	22.1	31.2	48.3
DA-3	3.31	5.5	12.1	17.0	26.3
DA-4	2.72	5.1	11.3	15.8	24.3
DA-5	4.23	6.5	14.4	20.2	31.2
DA-6	11.13	14.4	32.2	45.5	70.7
DA-7	2.85	4.7	10.3	14.5	22.4
DA-8	2.61	4.8	10.5	14.7	22.6
DA-9	3.52	6.4	14.2	19.9	30.6
DA-10	1.88	4.8	9.2	12.3	18.2
DA-11	0.65	1.4	2.9	3.9	6.0
DA-12	1.07	2.6	5.1	6.9	10.3
NPC-1	1.01	2.3	4.6	6.2	9.4
NPC-2	1.14	2.8	5.4	7.3	10.9
NPC-3	1.58	3.9	7.6	10.3	15.2



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SPC-1	0.97	2.5	4.7	6.4	9.4
SPC-2	1.64	4	7.8	10.6	15.7
SPC-3	0.74	1.9	3.6	4.9	7.2
SPC-4	1.54	3.8	7.3	9.9	14.7
North Water Surface	0.60	3.0	4.7	5.9	8.0
Central Water Surface	0.92	4.5	7.1	8.8	12.0
South Water Surface	0.59	3.0	4.7	5.9	8.0
Perimeter Channels and Culverts	DA (Ac)	Q <sub>2</sub> (CFS)	Q <sub>10</sub> (CFS)	Q <sub>25</sub> (CFS)	Q <sub>100</sub> (CFS)
NPC-01	1.01	2.3	4.6	6.2	9.3
NPC-02	4.66	9.3	19.5	27	40.9
NPC-03	13.42	21.9	46.7	65.1	99.5
2 x 36" Pipe	16.73	26.7	57.9	81.1	124.3
SPC-01	0.97	2.4	4.7	6.3	9.3
SPC-02	5.33	11.3	23.3	32.2	48.7
SPC-03	10.30	18.9	40.3	56.2	85.7
SPC-04	22.97	35.1	76.4	107.1	164.3
SB Ditch	29.10	37.7	84.1	118.7	184.0
Sedin	nent Basins	and Comp	onents		
C-N Weir		2.6	7.1	11.1	18.7
C-S Weir		2.6	7.1	11.1	18.7
North Basin in	17.33	29.3	65.2	92.5	143.9
North Basin out		9.0	50.0	79.5	130.6
North Basin HW Elevation		26.4	27.0	27.3	27.8
Central Basin in	6.30	13.0	25.8	35.1	52.4
Central Basin out*		2.6	7.1	11.1	18.7
Central Basin HW Elevation		27.3	27.5	27.6	27.8
South Basin in	30.76	43.4	99.8	143.0	224.8
South Basin out		24.7	87.1	130.6	209.5
South Basin HW Elevation		26.7	27.4	27.8	28.4

\*Central Basin discharges to North and South basins

Largest Bench	4.58	5.9	13.2	18.7	29.1
Largest Inlet	4.23	6.5	14.4	20.2	31.2

Calculations for the HEC-HMS input and output are attached.

# Sideslope Bench Capacity Hydraulics

For the largest sideslope bench drainage area of 4.58 acres, the capacity of the berm to convey water to the downslope pipe inlet was evaluated. Stormwater runoff calculations for the bench capacity were made using the Manning's equation.



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The top deck diversion berms have a V-ditch cross sectional shape which is formed when the 45:1 (approximate 2%) landfill side slope meets the constructed berm. The resulting cross section has side slopes of 45:1 and 3:1, and a depth of 2.5 feet. At the 25-year storm event, the bench with the largest individual drainage area is capable of conveying the flow with a freeboard of 1.8-feet. For the 10-year storm, 1.9-feet of freeboard is provided. Flow velocity at the 2-year event is calculated at 1.33 ft/sec, and a non-biodegradable erosion control matting (EC-3 equivalent) is specified.

Calculations for the side slope bench (and other perimeter channels) are attached. The constructed depth of the berms is driven by the downslope pipe inlets rather than the capacity of the berm, as explained in the next section.

# **Downslope Pipe and Inlet Capacity**

At the low point of each of the diversion berms, a 24-inch diameter drop inlet will receive the flow into a 24-inch diameter HDPE downslope pipe. The inlets were evaluated to verify sufficient capacity exists at each inlet to accept flow and provide at least one-half foot of freeboard for the 25-year storm event. A single 24" inlet and side slope berms constructed to an effective depth of 2.5 feet is sufficient to convey the 25-year storm event with a freeboard of 0.6-feet.

The downslope pipe conveying flow from the largest contributing drainage area is DA-5 on the southwestern portion of the landfill. The computed 25-year storm flow for the 4.23-acre drainage area is 20.2 CFS. The capacity of the downslope pipes is approximately 140.8 CFS. Calculation spreadsheets are attached.

At the terminal end of each downslope pipe, a stilling basin box will be constructed to attenuate the concentrated flow from the pipe and let it into the perimeter channel in a non-erosive manner. Capacity calculations are attached.

### **Perimeter Channel Capacity**

The capacity for the proposed perimeter channels were evaluated for the 10 and 25-year storm event. The previously constructed channels do not have adequate capacity based on their associated constructed depth. The below table provides the minimum channel depth required based on a trapezoidal channel section with 3H:1V side slopes. Channel lining of non-biodegradable erosion control matting (EC-3 equivalent) is specified based on the 2-year velocity. Calculation spreadsheets are attached.

**Table 3: Perimeter Channel Schedule** 

Perimeter Channel	Q <sub>2</sub> (CFS)	V <sub>2</sub> (fps)	Q <sub>25</sub> (CFS)	Flow Depth – 10yr (in)	Freeboard 10yr (in)	Flow Depth – 25yr (in)	Freeboard 25yr (in)	Minimum Channel Depth (ft)
NPC-01	2.3	2.03	6.2	4.3	7.7	5.0	7.0	1.0
NPC-02	9.3	2.82	27	10.2	7.8	12.1	5.9	1.5
NPC-03	21.9	3.17	65.1	17.3	6.7	20.3	3.7	2.0
SPC-01	2.4	2.06	6.3	4.3	7.7	5.1	6.9	1.0
SPC-02	11.3	2.02	32.2	14.8	9.2	17.3	6.7	2.0
SPC-03	18.9	2.76	56.2	17.2	6.8	20.2	3.8	2.0
SPC-04	35.1	3.00	107.1	24.6	5.4	28.7	1.3	2.5
SB Ditch	37.7	3.66	118.7	22.9	7.1	26.9	3.1	2.5



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### **Culvert Capacity**

Existing culverts in the surface water management system have been evaluated to confirm adequate capacity has been provided for the 25-year storm. Two (2) existing 36-inch diameter culverts convey flow from the northern perimeter channels to the northern sediment basin. The transition occurs in the northeast corner of the landfill. On the southeastern corner of the landfill three (3), 36-inch diameter culverts convey flow from the southern perimeter channels to the southern basin ditch. Within the ditch are two (2) additional 36-inch diameter culverts. Along the northeastern edge of the landfill a singular 24-inch diameter culvert conveys flow to the southern sediment basin from DA-12 and a separate 24-inch diameter culvert conveys flow to the northern sediment basin from DA-11. Finally, two (2) 36-inch diameter culverts convey flow from DA-7 and DA-10 to the central sediment basin. Calculation spreadsheets are attached. CulvertMaster was utilized to calculate flow when headwater condition is present. Spreadsheet analysis was used for open channel flow conditions.

# **Stormwater Basin Evaluation**

The network of three (3) stormwater basins at the landfill were evaluated to provide function for erosion and sediment control capacity as well as attenuation for the 25-year storm event.

In order to provide a freeboard of at least 1.0-foot for the 25-year storm event, the top of basin berm will be required to be raised to a minimum elevation 28.8. The increase in elevation will provide adequate sizing for the 25-year event. Please see the attached calculation spreadsheets.

# **ATTACHMENTS**

Attachment 1: Drainage Area Map (Drawing 1)

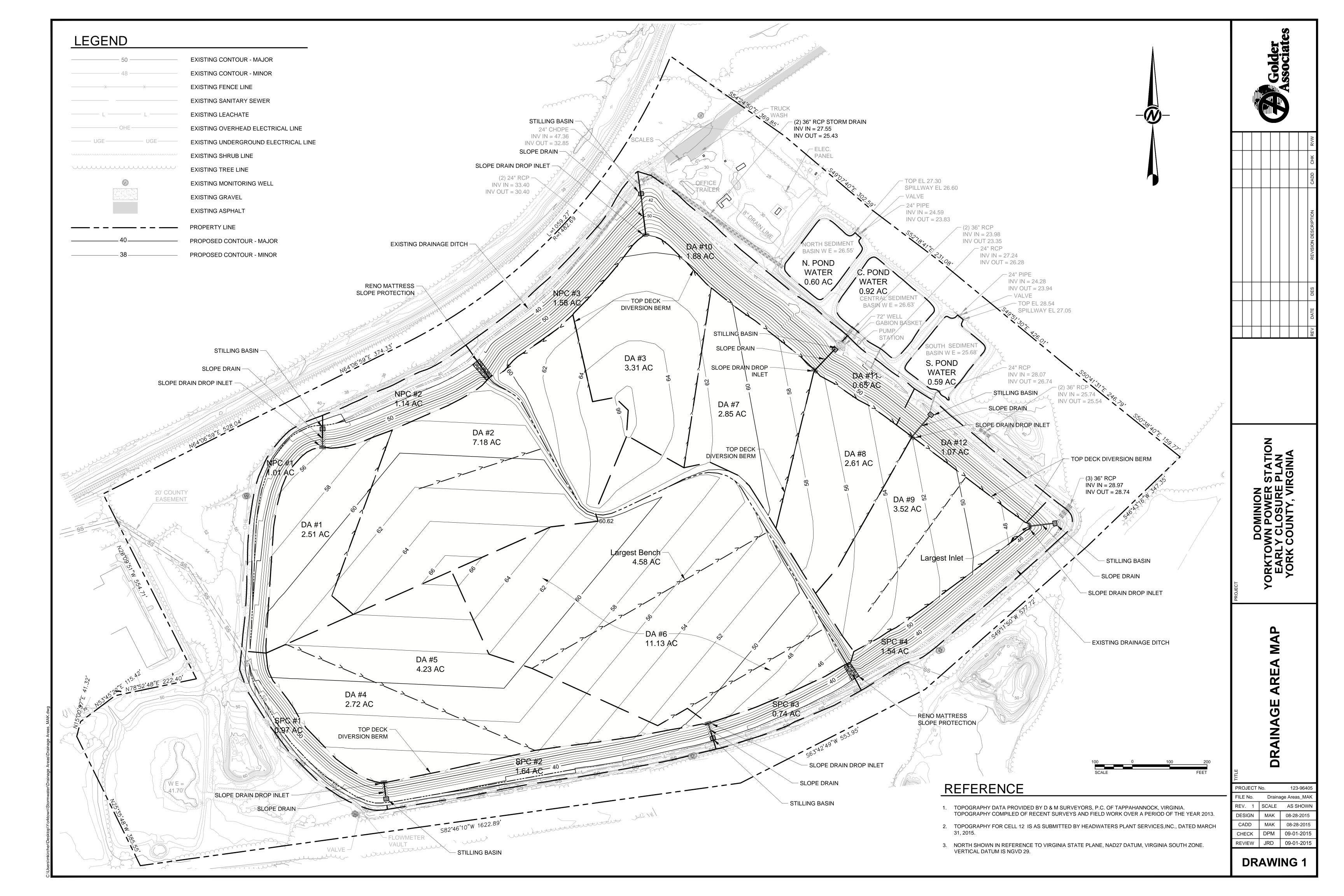
Attachment 2: Individual component calculation spreadsheets or packages:

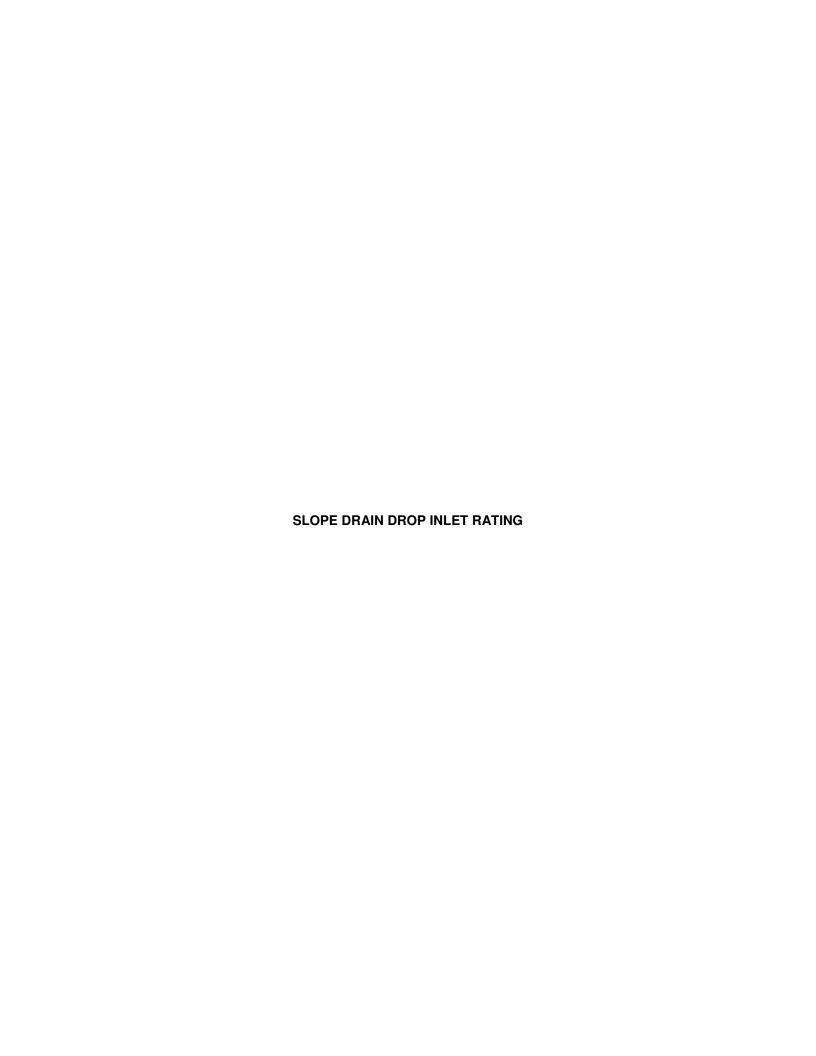
- Slope Drain Drop Inlet Rating;
- Slope drain pipe capacity and stilling basin
- Diversion Berm, Perimeter channel capacity, and Culvert capacity worksheets

### References

- 1) U.S. Army Corps of Engineers Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS) release 4.0
- 2) National Oceanic and Atmospheric Administration (NOAA), Point Precipitation Frequency Estimates for NOAA Atlas 14, http://hdsc.nws.noaa.gov/hdsc/pfds/index.html
- 3) Brater, Ernest; King, Horace; Handbook of Hydraulics 7th Ed, 1996
- Natural Resources Conservation Service (NRCS), "Web Soil Survey", http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx
- 5) Bentley Systems, Inc CulvertMaster v3.3.







### Given Data

Pipe Inside Dia	2	ft
Cd (Orifice)	0.6	
Cw (Weir)	3.33	
Pipe Area, A	2.67	
Pipe Opening, L	5.34	

Nominal Pipe Area	3.14159
% open area	85%
Inlet Crest Elevation	0

(assumed obstructed)

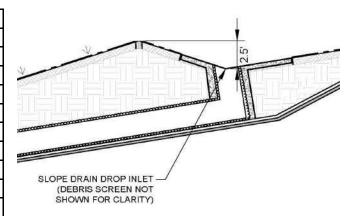
Use:

Orifice Equation Q = A\*Cd\*sqrt (2 \*g \* H)

Weir Equation  $Q = Cw * L * H^1.5$ 

A vertical pipe used as an inlet will act first as a weir, then at a certain depth, will transition to an orifice flow. This depth depends on the diameter of the pipe. Use the lower of the two values for the actual expected flow from the riser.

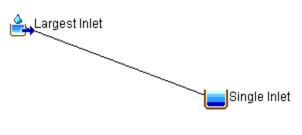
Rated Capacity of one Slope Drain Drop Inlet						
	CFS	CFS	Minimum	Controlling		
Head, ft	Orifice	Weir	Value, CFS	Flow		
0	0	0	0.00	N/A		
0.25	6.43	2.22	2.22	WEIR		
0.5	9.09	6.29	6.29	WEIR		
0.75	11.14	11.55	11.14	ORIFICE		
1	12.86	17.78	12.86	ORIFICE		
1.25	14.38	24.85	14.38	ORIFICE		
1.5	15.75	32.67	15.75	ORIFICE		
1.75	17.01	41.17	17.01	ORIFICE		
2.0	18.18	50.30	18.18	ORIFICE		
2.25	19.29	60.02	19.29	ORIFICE		
2.5	20.33	70.30	20.33	ORIFICE		



**HEC-HMS Modeled Results for inlet analysis** 

		25-Yr Event		
	Area, Ac.	Flow, CFS	Head, ft	Freeboard
Largest Drop Inlet	4.23	17.6	1.9	0.6

The inlet was modeled in HEC-HMS as a small reservoir to account for the stage storage volume that temporarily develops at the inlet during large storm events. The inlets as designed with 85% open function for the 25-year event.





Made By: MAK

Checked: Reviewed:





Subject: Slope drain and stilling basins at the Dominion - Yorktown Landfill in Yorktown, Virginia				
Job No:	12396405	Made by: MAK	Date:	8/28/15
	Rev	v 0 Checked:		
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# **Objective**

Determine the capacity of the slope drain and the stilling basins that will be located at the base of the slope drain

### **Calculation**

Slope Drain

Where: Q = flowrate, cfs

 $Q = \frac{1.486}{n} A R^{2/3} S^{1/2}$ 

A= cross-sectional area, sq ft =  $\pi/4 * dia^2$ R= hyrdaulic radis, ft = dia/4 (assuming full)

S= downchute slope, ft/ft = 0.33 (3:1 on slopes)
n = Manning number = 0.012 smooth

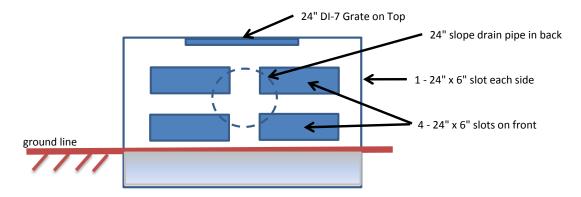
With diameter = 24"

Qfull =

II = 140.8 cfs

Slope drain Pipe ID	Drainage area (Ac.)	Q <sub>25</sub> (cfs)	Flow depth (ft)	Flow velocity (ft/s)	% Full
DA-1	2.51	13.8	0.47	30.26	10%
DA-3	3.31	17.0	0.51	31.89	12%
DA-4	2.72	15.8	0.50	31.31	11%
DA-5	4.23	25.3	0.61	35.23	18%
DA-7	2.85	14.5	0.48	30.64	10%
DA-8	2.61	14.7	0.48	30.75	10%
DA-9	3.52	19.9	0.55	33.18	14%

# Stilling Basin





Subject:	ject: Slope drain and stilling basins at the Dominion - Yorktown Landfill in Yorktown, Virginia			
Job No:	12396405	Made by: MAK	Date:	8/28/15
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		_
Slot height	6	inches
slot width	24	
Hole area	1	ft <sup>2</sup>
holes/row 1	2	
holes/row 2	4	
row 1 crest	3	inches from bottom
row 2 crest	18	inches from bottom

Depth in Box	H1	H2	Q/hole1	Q/row1	Q/hole2	Q/row2	Total	
. 0	0	0	0			•	0	
3	0	0	0	0			0	
6	0.25	0	1.04	2.08	0.00	0.00	2.08	cfs
9	0.5	0	2.94	5.89	0.00	0.00	5.89	cfs
12	0.75	0	4.17	8.34	0.00	0.00	8.34	cfs
15	1	0	4.81	9.63	0.00	0.00	9.63	cfs
18	1.25	0	5.38	10.77	0.00	0.00	10.77	cfs
21	1.5	0.25	5.90	11.79	1.04	4.16	15.96	cfs
24	1.75	0.5	6.37	12.74	2.94	11.77	24.51	cfs
27	2	0.75	6.81	13.62	4.17	16.68	30.30	cfs
30	2.25	1	7.22	14.44	4.81	19.26	33.70	cfs
33	2.5	1.25	7.61	15.23	5.38	21.53	36.76	cfs
36	2.75	1.5	7.98	15.97	5.90	23.59	39.56	cfs
39	3	1.75	8.34	16.68	6.37	25.48	42.16	cfs
42	3.25	2	8.68	17.36	6.81	27.24	44.60	cfs

<sup>\*\*</sup> Flows in excess of 44.6 CFS will convey out the top DI-7 grate

#### Conclusion

Based on the results of this model, the downslope pipes and the stilling basins with 6-24"x6" holes adequately convey the 25-year, 24 hour storm event.

References 1) Brater, Ernest; King, Horace; Handbook of Hydraulics 7th Ed, 1996



#### NPC-01

Channel Dimensions					
Bw:	4	ft	Top width:	10	ft
Length:	690	ft	Offset (LB):	5	
Elev <sub>0</sub> :		ft	Offset (RB):	5	
Elev <sub>1</sub> :		ft			
Δ Elev:		ft	Min. Depth:	1	ft
Slope:	0.019	ft/ft	Left Slope	3	: 1
	1.88	%	Right Slope	3	: 1

Flow Depth (2yr):				
Q:	2.3	cfs		
Depth:	2.9	in		
	0.240	ft		
Freeboard:	9.1	in		

Manning's Equation (2yr):				
n:	0.035			
A:	1.132	sqft		
P:	5.517	ft		
R:	0.205	ft/ft		
S:	0.0188	ft/ft		
Q =	2.3	cfs		
V =	2.03	ft/s		

Travel time =	5.66	min

Flow Depth (10yr):					
<b>Q:</b> 4.6 cfs					
Depth:	4.3	in			
	0.356	ft			
Freeboard:	7.7	in			

Manning's Equation (10yr):				
n:	0.035			
A:	1.804	sqft		
P:	6.252	ft		
R:	0.289	ft/ft		
S:	0.0188	ft/ft		
Q =	4.6	cfs		
V =	2.55	ft/s		

Travel time =	4.51	min

Flow Depth (25yr):				
<b>Q:</b> 6.2 cfs				
Depth:	5.0	in		
	0.421	ft		
Freeboard:	7.0	in		

Manning's Equation (25yr):				
n:	0.035			
A:	2.214	sqft		
P:	6.661	ft		
R:	0.332	ft/ft		
S:	0.0188	ft/ft		
Q =	6.2	cfs		
V =	2.80	ft/s		

el time =	4.51	min	Travel time =	4.11	min

Flow Depth (25yr):			Flow	Depth (10	0yr):
Q:	6.2	cfs	Q:	9.3	cfs
th:	5.0	in	Depth:	6.3	in
	0.421	ft		0.526	ft
rd:	7.0	in	Freeboard:	5.7	in

Manning's Equation (100yr):				
n:	0.035			
A:	2.933	sqft		
P:	7.326	ft		
R:	0.400	ft/ft		
S:	0.0188	ft/ft		
Q =	9.3	cfs		
V =	3.17	ft/s		
	•	•		

Travel time = 3	63 min
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Channel Dimensions					
Bw:	4	ft	Top width:	13	ft
Length:	445.0	ft	Offset (LB):	6.5	
Elev <sub>0</sub> :		ft	Offset (RB):	6.5	
Elev <sub>1</sub> :		ft			
Δ Elev:	0	ft	Depth:	1.5	ft
Slope:	0.014	ft/ft	Left Slope	3	: 1
	1.35	%	Right Slope	3	: 1

Flow Depth (2yr):			
Q:	9.3	cfs	
Depth:	6.9	in	
	0.575	ft	
Freeboard:	11.1	in	

Flow Depth (10yr):			
Q:	19.5	cfs	
Depth:	10.2	in	
	0.851	ft	
Freeboard:	7.8	in	

Flow Depth (25yr):			
Q:	27.0	cfs	
Depth:	12.1	in	
	1.005	ft	
Freeboard:	5.9	in	

Flow Depth (100yr):			
Q:	40.9	cfs	
Depth:	14.8	in	
	1.237	ft	
Freeboard:	3.2	in	

Manning's Equation (2yr):				
n:	0.035			
A:	3.294	sqft		
P:	7.638	ft		
R:	0.431	ft/ft		
S:	0.0135	ft/ft		
Q =	9.3	cfs		
V =	2.823	ft/s		
		·		

Manning's Equation (10yr):			
n:	0.035		
A:	5.577	sqft	
P:	9.382	ft	
R:	0.594	ft/ft	
S:	0.0135	ft/ft	
Q =	19.5	cfs	
V =	3.497	ft/s	

Manning's Equation (25yr):				
n:	0.035			
A:	7.053	sqft		
P:	10.358	ft		
R:	0.681	ft/ft		
S:	0.0135	ft/ft		
Q =	27.0	cfs		
V =	3.828	ft/s		

Manning's Equation (100yr):			
n:	<b>n:</b> 0.035		
A:	9.541	sqft	
P:	11.825	ft	
R:	0.807	ft/ft	
S:	0.0135	ft/ft	
Q =	40.9	cfs	
V =	4.287	ft/s	

Travel time =	2.63	min

Travel time =	2.12	min

Travel time =	1.94	min
riaver time =	1.54	111111

Travel time =	1.73	min
Travel time	1., 3	

### NPC-03

Channel Dimensions					
Bw:	4	ft	Top width:	16	ft
Length:	640	ft	Offset (LB):	8	
Elev <sub>o</sub> :		ft	Offset (RB):	8	
Elev <sub>1</sub> :		ft			
Δ Elev:	0	ft	Depth:	2	ft
Slope:	0.009	ft/ft	Left Slope	3	: 1
	0.94	%	Right Slope	3	: 1

Flow Depth (2yr):			
<b>Q:</b> 21.9 cfs			
Depth:	11.9	in	
	0.991	ft	
Freeboard:	12.1	in	

Flow Depth (10yr):		
Q:	46.7	cfs
Depth:	17.3	in
	1.442	ft
Freeboard:	6.7	in

Flow Depth (25yr):				
<b>Q:</b> 65.1 cfs				
Depth:	20.3	in		
	1.690	ft		
Freeboard:	3.7	in		

Flow Depth (100yr):			
<b>Q:</b> 99.5 cfs			
Depth:	24.7	in	
	2.061	ft	
Freeboard:	-0.7	in	

Manning's Equation (2yr):			
n:	0.035		
A:	6.909	sqft	
P:	10.267	ft	
R:	0.673	ft/ft	
S:	0.0094	ft/ft	
Q =	21.9	cfs	
V =	3.170	ft/s	
•		•	

Manning's Equation (10yr):				
n:	<b>n:</b> 0.035			
A:	12.004	sqft		
P:	13.119	ft		
R:	0.915	ft/ft		
S:	0.0094	ft/ft		
Q =	46.7	cfs		
V =	3.890	ft/s		

Manning's Equation (25yr):		
n:	0.035	
A:	15.330	sqft
P:	14.689	ft
R:	1.044	ft/ft
S:	0.0094	ft/ft
Q =	65.1	cfs
V =	4.247	ft/s

Manning's Equation (100yr):		
n:	0.035	
A:	20.979	sqft
P:	17.032	ft
R:	1.232	ft/ft
S:	0.0094	ft/ft
Q =	99.5	cfs
V =	4.743	ft/s

Travel time =	3.37	min

Travel time =	2.74	min

Travel time =	2.51	min
	2.01	

Travel time =	2.25	min
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# 2 x 36" pipe (Northern Channels)

Pipe Dimensions		
Diameter:	36	in
	3	ft
Radius:	1.5	ft
# of Pipes:	2	
Initial Elev:	30	ft
Terminal Elev:	27.87	ft
Δ Elevation:	2.13	ft
Length:	426	ft

Converter		
gpm	0	
cfs	0	
cfs	0	
gpm	0	

Flow Depth (2yr):			
<b>y:</b> 14.0 in			
	1.167	ft	
θ:	2.694379		

Flow Depth (10yr):			
<b>y:</b> 22.3 in			
	1.862	ft	
θ:	3.629646		

Flow Depth (25yr):		
y:	29.2	in
	2.434	ft
θ:	4.485757	

Manning's Equation (2yr):			
n:	0.013		
A:	2.545	sqft	
R:	0.630	ft/ft	
S:	0.0050	ft/ft	
Q Total:	26.70	cfs	
Q Req/Pipe:	13.35	cfs	
Q =	15.15	cfs	
V =	5.954	ft/s	

	Manning's Equation (10yr):			
	n:	0.013		
	A:	4.611	sqft	
	R:	0.847	ft/ft	
	S:	0.0050	ft/ft	
	Q Total	57.90	cfs	
Q	Req/Pipe:	28.95	cfs	
	Q =	33.45	cfs	
	V =	7.255	ft/s	
_			•	

	Manning's Equation (25yr):			
	n:	0.013		
	A:	6.143	sqft	
	R:	0.913	ft/ft	
	S:	0.0050	ft/ft	
	Q Total	81.10	cfs	
Q	Req/Pipe:	40.55	cfs	
	Q =	46.85	cfs	
	V =	7.627	ft/s	

Travel time =	1.19	min
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ravel time =	0.98	min	

Channel Dimensions					
Bw:	4	ft	Top width:	10	ft
Length:	585	ft	Offset (LB):	5	
Elev <sub>0</sub> :		ft	Offset (RB):	5	
Elev <sub>1</sub> :		ft			
Δ Elev:	0	ft	Depth:	1	ft
Slope:	0.019	ft/ft	Left Slope	3	: 1
	1.88	%	Right Slope	3	: 1

Flow Depth (2yr):				
<b>Q:</b> 2.4 cfs				
Depth:	3.0	in		
	0.246	ft		
Freeboard:	9.0	in		

Flov	Flow Depth (10yr):			
<b>Q:</b> 4.7 cfs				
Depth:	4.3	in		
	0.360	ft		
Freeboard:	7.7	in		

Flow Depth (25yr):				
<b>Q:</b> 6.3 cfs				
Depth:	5.1	in		
	0.424	ft		
Freeboard: 6.9 in				

Flow Depth (100yr):				
<b>Q:</b> 9.3 cfs				
Depth:	6.3	in		
	0.526	ft		
Freeboard:	5.7	in		

Manning's Equation (2yr):				
n:	0.035			
A:	1.165	sqft		
P:	5.555	ft		
R:	0.210	ft/ft		
S:	0.0188	ft/ft		
Q =	2.4	cfs		
V =	2.060	ft/s		

Manning's Equation (10yr):					
n:	0.035				
A:	1.831	sqft			
P:	6.279	ft			
R:	0.292	ft/ft			
S:	0.0188	ft/ft			
Q =	4.7	cfs			
V =	2.567	ft/s			

Manning's Equation (25yr):			
n:	0.035		
A:	2.238	sqft	
P:	6.684	ft	
R:	0.335	ft/ft	
S:	0.0188	ft/ft	
Q =	6.3	cfs	
V =	2.815	ft/s	

Manning's Equation (100yr):			
0.035			
2.933	sqft		
7.326	ft		
0.400	ft/ft		
0.0	ft/ft		
9.3	cfs		
3.171	ft/s		
	0.035 2.933 7.326 0.400 0.0		

Travel time =	4.73	min

Travel time =	3.80	min

Travel time =	3.46	min

Travel time =	3.07	min

Channel Dimensions					
Bw:	4	ft	Top width:	16	ft
Length:	890	ft	Offset (LB):	8	
Elev <sub>o</sub> :		ft	Offset (RB):	8	
Elev <sub>1</sub> :		ft			
Δ Elev:	0	ft	Depth:	2.0	ft
Slope:	0.004	ft/ft	Left Slope	3	: 1
	0.449	%	Right Slope	3	: 1

Flow Depth (2yr):				
<b>Q:</b> 11.3 cfs				
Depth:	10.2	in		
	0.853	ft		
Freeboard:	13.8	in		

Flow Depth (10yr):				
<b>Q:</b> 23.3 cfs				
Depth:	14.8	in		
	1.230	ft		
Freeboard:	9.2	in		

Flow Depth (25yr):				
<b>Q:</b> 32.2 cfs				
Depth:	17.3	in		
	1.440	ft		
Freeboard:	6.7	in		

Flow Depth (100yr):			
<b>Q:</b> 48.7 cfs			
Depth:	21.1	in	
	1.754	ft	
Freeboard: 2.9 in			

Manning's Equation (2yr):				
n:	0.035			
A:	5.596	sqft		
P:	9.396	ft		
R:	0.596	ft/ft		
S:	0.0045	ft/ft		
Q =	11.3	cfs		
V =	2.019	ft/s		
*				

Manning's Equation (10yr):			
n:	0.035		
A:	9.456	sqft	
P:	11.777	ft	
R:	0.803	ft/ft	
S:	0.0045	ft/ft	
Q =	23.3	cfs	
V =	2.464	ft/s	
•	•	•	

Manning's Equation (25yr):			
n:	<b>n:</b> 0.035		
A:	11.984	sqft	
P:	13.109	ft	
R:	0.914	ft/ft	
S:	0.0045	ft/ft	
Q =	32.2	cfs	
V =	2.687	ft/s	

Manning's Equation (100yr):				
n:	0.035			
A:	16.253	sqft		
P:	15.096	ft		
R:	1.077	ft/ft		
S:	<b>S:</b> 0.0045			
Q =	48.7	cfs		
V =	2.996	ft/s		

Travel time =	7.35	min

Travel time =	6.02	min

Travel time =	5.52	min

Travel time =	4.05	min
maver time =	4.55	111111

Channel Dimensions					
Bw:	4	ft	Top width:	16	ft
Length:	415	ft	Offset (LB):	8	
Elev <sub>0</sub> :		ft	Offset (RB):	8	
Elev <sub>1</sub> :		ft			
Δ Elev:	0	ft	Depth:	2	ft
Slope:	0.007	ft/ft	Left Slope	3	: 1
	0.72	%	Right Slope	3	: 1

Flow Depth (2yr):				
<b>Q:</b> 18.9 cfs				
Depth:	11.8	in		
0.984 ft				
Freeboard:	12.2	in		

Flow Depth (10yr):			
<b>Q:</b> 40.3 cfs			
Depth:	17.2	in	
	1.432	ft	
Freeboard:	6.8	in	

Flow Depth (25yr):			
<b>Q:</b> 56.2 cfs			
Depth:	20.2	in	
1.679 ft			
Freeboard:	3.8	in	

Flow Depth (100yr):			
<b>Q:</b> 85.7 cfs			
Depth:	24.5	in	
2.045 ft			
Freeboard:	-0.5	in	

Manning's Equation (2yr):			
n:	0.035		
A:	6.840	sqft	
P:	10.223	ft	
R:	0.669	ft/ft	
S:	0.0072	ft/ft	
Q =	18.9	cfs	
V =	2.763	ft/s	
•		•	

Manning's Equation (10yr):			
n:	0.035		
A:	11.881	sqft	
P:	13.057	ft	
R:	0.910	ft/ft	
<b>S:</b> 0.0072		ft/ft	
Q =	40.3	cfs	
V =	3.392	ft/s	

Manning's Equation (25yr):		
n:	0.035	
A:	15.176	sqft
P:	14.620	ft
R:	1.038	ft/ft
S:	0.0072	ft/ft
Q =	56.2	cfs
V =	3.703	ft/s

Manning's Equation (100yr):		
n:	0.035	
A:	20.732	sqft
P:	16.936	ft
R:	1.224	ft/ft
S:	0.0072	ft/ft
Q =	85.7	cfs
V =	4.134	ft/s

Travel time =	2.50	min

Travel time =	2.04	min

Travel time =	1 87	min
iravei tiirie =	1.07	111111

Travel time =	1.67	min
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Channel Dimensions					
Bw:	4	ft	Top width:	19	ft
Length:	700	ft	Offset (LB):	9.5	
Elev <sub>0</sub> :		ft	Offset (RB):	9.5	
Elev <sub>1</sub> :		ft			
Δ Elev:	0	ft	Depth:	2.5	ft
Slope:	0.006	ft/ft	Left Slope	3	: 1
	0.57	%	Right Slope	3	: 1

Flow Depth (2yr):			
<b>Q:</b> 35.1 cfs			
Depth:	17.0	in	
1.417 ft			
Freeboard:	13.0	in	

Flow Depth (10yr):			
<b>Q:</b> 76.4 cfs			
Depth:	24.6	in	
	2.047	ft	
Freeboard:	5.4	in	

Flow Depth (25yr):			
<b>Q:</b> 107.1 cfs			
Depth:	28.7	in	
	2.389	ft	
Freeboard:	1.3	in	

Flow Depth (100yr):				
<b>Q:</b> 164.3 cfs				
Depth:	34.7	in		
2.893 ft				
Freeboard: -4.7 in				

Manning's Equation (2yr):				
n:	0.035			
A:	11.696	sqft		
P:	12.964	ft		
R:	0.902	ft/ft		
S:	0.0057	ft/ft		
Q =	35.1	cfs		
V =	3.001	ft/s		
•				

Manning's Equation (10yr):				
n:	<b>n:</b> 0.035			
A:	20.762	sqft		
P:	16.948	ft		
R:	1.225	ft/ft		
S:	0.0057	ft/ft		
Q =	76.4	cfs		
V =	3.680	ft/s		

Manning's Equation (25yr):				
n:	0.035			
A:	26.677	sqft		
P:	19.109	ft		
R:	1.396	ft/ft		
S:	0.0057	ft/ft		
Q =	107.1	cfs		
V =	4.015	ft/s		

Manning's Equation (100yr):				
n:	0.035			
A:	36.682	sqft		
P:	22.297	ft		
R:	1.645	ft/ft		
S:	0.0057	ft/ft		
Q =	164.3	cfs		
V =	4.479	ft/s		

Travel time =	3.89	min

Travel time =	3.17	min

Travel time =	2.91	min

Travel time =	2.60	min

## SB DITCH

Channel Dimensions					
Bw:	4	ft	Top width:	19	ft
Length:	430	ft	Offset (LB):	9.5	
Elev <sub>o</sub> :		ft	Offset (RB):	9.5	
Elev <sub>1</sub> :		ft			
Δ Elev:	0	ft	Depth:	2.5	ft
Slope:	0.009	ft/ft	Left Slope	3	: 1
	0.93	%	Right Slope	3	: 1

Flow Depth (2yr):					
<b>Q:</b> 37.7 cfs					
Depth:	15.6	in			
1.303 ft					
Freeboard:	14.4	in			

Flow Depth (10yr):				
<b>Q:</b> 84.1 cfs				
Depth:	Depth: 22.9			
1.911 ft				
Freeboard:	Freeboard: 7.1			

Flow Depth (25yr):					
<b>Q:</b> 118.7 cfs					
Depth:	26.9	in			
	2.240 ft				
Freeboard: 3.1 in					

Flow Depth (100yr):			
<b>Q:</b> 184 cfs			
Depth:	32.7	in	
	2.729	ft	
Freeboard:	-2.7	in	

Manning's Equation (2yr):			
n:	0.035		
A:	10.301	sqft	
P:	12.239	ft	
R:	0.842	ft/ft	
S:	0.0093	ft/ft	
Q =	37.7	cfs	
V =	3.660	ft/s	
·		·	

Manning's Equation (10yr):					
n:	0.035				
A:	18.596	sqft			
P:	16.085	ft			
R:	1.156	ft/ft			
S:	0.0093	ft/ft			
Q =	84.1	cfs			
V =	4.522	ft/s			

Manning's Equation (25yr):			
n:	0.035		
A:	24.008	sqft	
P:	18.165	ft	
R:	1.322	ft/ft	
S:	0.0093	ft/ft	
Q =	118.7	cfs	
V =	4.944	ft/s	
	•		

Manning's Equation (100yr):					
n:	<b>n:</b> 0.035				
A:	33.258	sqft			
P:	21.260	ft			
R:	1.564	ft/ft			
S:	0.0093	ft/ft			
Q =	184.0	cfs			
V =	5.532	ft/s			

Travel time =	1.96	min

Travel time =	1 52	min
i aver tille =	1.50	111111

Travel time =	1.45	min

Travel time =	1.30	min
a ver time	1.50	

# Largest Bench

Channel Dimensions					
Bw:	0	ft	Top width:	72	ft
Length:	722	ft	Offset (LB):	67.5	
Elev <sub>0</sub> :		ft	Offset (RB):	4.5	
Elev <sub>1</sub> :		ft			
Δ Elev:	0	ft	Depth:	1.5	ft
Slope:	0.008	ft/ft	Left Slope	45	: 1
	0.76	%	Right Slope	3	: 1

Flow Depth (2yr):				
<b>Q:</b> 5.9 cfs				
Depth:	5.16	in		
0.430 ft				
Freeboard:	12.84	in		

Flow Depth (10yr):		
Q:	13.2	cfs
Depth:	6.98	in
	0.582	ft
Freeboard:	11.02	in

Flow Depth (25yr):			
<b>Q:</b> 18.7 cfs			
Depth:	7.95	in	
	0.663	ft	
Freeboard:	10.05	in	

Flow Depth (100yr):				
<b>Q:</b> 29.1 cfs				
Depth:	9.39	in		
	0.782	ft		
reeboard:	8.61	in		

Manning's Equation (2yr):				
n:	0.035			
A:	4.440	sqft		
P:	20.719	ft		
R:	0.214	ft/ft		
S:	0.0076	ft/ft		
Q =	5.9	cfs		
V =	1.33	ft/s		
•	·			

Manning's Equation (10yr):			
n:	0.035		
A:	8.122	sqft	
P:	28.023	ft	
R:	0.290	ft/ft	
S:	0.0076	ft/ft	
Q =	13.2	cfs	
V =	1.63	ft/s	

Manning's Equation (25yr):				
n:	0.035			
A:	10.546	sqft		
P:	31.933	ft		
R:	0.330	ft/ft		
S:	0.0076	ft/ft		
Q =	18.7	cfs		
V =	1.77	ft/s		

Manning's Equation (100yr):			
n:	0.035		
A:	14.694	sqft	
P:	37.693	ft	
R:	0.390	ft/ft	
S:	0.0076	ft/ft	
Q =	29.1	cfs	
V =	1.98	ft/s	

Travel time =	9.05	min

ravel time =	7.40	min

Travel time =	6.79	min

Travel time =	6.08	min
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# 3 x 36" pipe to SB Ditch

Pipe Dimensions		
Diameter:	36	in
	3	ft
Radius:	1.5	ft
# of Pipes:	3	
Initial Elev:	28.97	ft
Terminal Elev:	28.74	ft
Δ Elevation:	0.23	ft
Length:	40	ft

Converter		
gpm	0	
cfs	0	
cfs	0	
gpm	0	

Flow Depth (2yr):			
<b>y:</b> 11.8 in			
	0.980	ft	
θ:	2.433676		

Flow Depth (10yr):		
<b>y:</b> 18.0 in		in
	1.504	ft
θ:	3.146871	

Flow Depth (25yr):		
<b>y:</b> 22.3		in
	1.856	ft
θ:	3.62146	

Manning's Equation (2yr):		
n:	0.013	
A:	2.006	sqft
R:	0.550	ft/ft
S:	0.0058	ft/ft
Q Total:	35.1	cfs
Q Req/Pipe:	11.70	cfs
Q =	11.70	cfs
V =	5.831	ft/s

Manning's Equation (10yr):		
n:	0.013	
A:	3.546	sqft
R:	0.751	ft/ft
S:	0.0058	ft/ft
Q Total	76.4	cfs
Req/Pipe:	25.47	cfs
Q =	25.47	cfs
V =	7.182	ft/s
		•

Manning's Equation (25yr):		
n:	0.013	
A:	4.594	sqft
R:	0.846	ft/ft
S:	0.0058	ft/ft
Q Total	107.1	cfs
Req/Pipe:	35.70	cfs
Q =	35.70	cfs
V =	7.772	ft/s

Travel time =	0.11	min
---------------	------	-----

ravel time =	0.09	min	

# SB Ditch Culverts 2 x 36" pipe

Pipe Dimensions		
Diameter:	36	in
	3	ft
Radius:	1.5	ft
# of Pipes:	2	
Initial Elev:	25.74	ft
Terminal Elev:	25.54	ft
Δ Elevation:	0.2	ft
Length:	32	ft

Conv	erter
gpm	0
cfs	0
cfs	0
gpm	0

Flow Depth (2yr):			
y:	14.9	in	
	1.238	ft	
θ:	2.790057		

Flow Depth (10yr):			
<b>y:</b> 24.3 in			
	2.021	ft	
θ:	3.851167		

Manning's Equation (2yr):			
n:	0.013		
A:	2.751	sqft	
R:	0.657	ft/ft	
S:	0.0062	ft/ft	
Q Total:	37.70	cfs	
Q Req/Pipe:	18.85	cfs	
Q =	18.85	cfs	
V =	6.851	ft/s	

Manning's Equation (10yr):				
n:	0.013			
A:	5.066	sqft		
R:	0.877	ft/ft		
S:	0.0062	ft/ft		
Q Total	84.10	cfs		
Req/Pipe:	42.05	cfs		
Q =	42.05	cfs		
V =	8.301	ft/s		

Travel time =	0.08	min

Travel time =	0.06	min

	Flo	w De	epth (25yr):		
Culvert Summary	<i>y</i> -		· · · · · · · · · · · · · · · · · · ·		
Allowable HW Elevation	4.00	ft	Headwater Depth/Height	1.60	
Computed Headwater Elevation	on 5.01	ft	Discharge	118.70	cfs
Inlet Control HW Elev.	5.01	ft	Tailwater Elevation	2.25	ft
Outlet Control HW Elev.	4.73	ft	Control Type	Inlet Control	
Grades					_
Upstream Invert	0.20	ft	Downstream Invert	0.00	ft
Length	32.00	ft	Constructed Slope	0.006250	ft/ft
Hydraulic Profile					
Profile	M2		Depth, Downstream	2.49	ft
Slope Type	Mild		Normal Depth	N/A	ft
Flow Regime	Subcritical		Critical Depth	2.49	ft
Velocity Downstream	9.46	ft/s	Critical Slope	0.007746	ft/fi
Section					
Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	3.00	ft
Section Size	36 inch		Rise	3.00	ft
Number Sections	2				_
Outlet Control Properties					_
Outlet Control HW Elev.	4.73	ft	Upstream Velocity Head	1.23	ft
Ke	0.50		Entrance Loss	0.62	ft
Inlet Control Properties					
Inlet Control HW Elev.	5.01	ft	Flow Control	Submerged	_
Inlet Type Squa	re edge w/headwall		Area Full	14.1	ft2
K	0.00980		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	1	
C	0.03980		Equation Form	1	
Y	0.67000				

DA-8 and DA-12 (1 x 24" pipe)

Pipe Dimensions			
Diameter:	24	in	
	2	ft	
Radius:	1	ft	
# of Pipes:	1		
Initial Elev:	28.07	ft	
Terminal Elev:	26.74	ft	
Δ Elevation:	1.33	ft	
Length:	50	ft	

Converter		
gpm	0	
cfs	0	
cfs	0	
gpm	0	

Flow Depth (2yr):			
y:	7.3	in	
	0.607	ft	
θ:	2.332957		

Flow Depth (10yr):				
<b>y:</b> 10.9 in				
	0.906	ft		
θ:	2.953881			

Flow Depth (25yr):			
y:	in		
1.098		ft	
θ:	3.337608		

Manning's Equation (2yr):		
n:	0.013	
A:	0.805	sqft
R:	0.345	ft/ft
S:	0.0266	ft/ft
Q Total:	7.40	cfs
Q Req/Pipe:	7.40	cfs
Q =	7.40	cfs
V =	9.195	ft/s

Manning's Equation (10yr):		
n:	0.013	
A:	1.384	sqft
R:	0.468	ft/ft
S:	0.0266	ft/ft
Q Total	15.60	cfs
Req/Pipe:	15.60	cfs
Q =	15.60	cfs
V =	11.275	ft/s
	·	

	Manning's Equation (25yr):		
	n:	0.013	
	A:	1.766	sqft
	R:	0.529	ft/ft
	S:	0.0266	ft/ft
	Q Total	21.60	cfs
Q	Req/Pipe:	21.60	cfs
	Q =	21.60	cfs
	V =	12.230	ft/s

Travel time = 0.09 min	

Travel time =	0.07	min

Travel time =	0.07	min

# DA-11 (1 x 24" culvert)

Pipe Dimensions		
Diameter:	24	in
	2	ft
Radius:	1	ft
# of Pipes:	1	
Initial Elev:	27.24	ft
Terminal Elev:	26.28	ft
Δ Elevation:	0.96	ft
Length:	57	ft

Converter		
gpm	0	
cfs	0	
cfs	0	
gpm	0	

Flow Depth (2yr):		
y:	3.6	in
	0.297	ft
θ:	1.58193	

Flow Depth (10yr):		
y:	5.1	in
	0.424	ft
θ:	1.913944	

Flow Depth (25yr):		
y:	5.9	in
	0.492	ft
θ:	2.075071	

<b>n:</b> 0.013	
<b>A:</b> 0.291 s	sqft
<b>R:</b> 0.184 f	ft/ft
<b>S:</b> 0.0168 f	ft/ft
<b>Q Total:</b> 1.40	cfs
Q Req/Pipe: 1.40	cfs
<b>Q</b> = 1.40	cfs
<b>V</b> = 4.811 f	ft/s

	Manning's Equation (10yr):		
	n:	0.013	
	A:	0.486	sqft
	R:	0.254	ft/ft
	S:	0.0168	ft/ft
	Q Total	2.90	cfs
Q	Req/Pipe:	2.90	cfs
	Q =	2.90	cfs
	V =	5.966	ft/s

Manning's Equation (25yr):				
n:	0.013			
A:	0.600	sqft		
R:	0.289	ft/ft		
S:	0.0168	ft/ft		
Q Total	3.90	cfs		
Req/Pipe:	3.90	cfs		
Q =	3.90	cfs		
V =	6.502	ft/s		

Travel time =	0.20	min

Travel time =	0.16	min

Travel time =	0.15	min

DA-7 & DA-10 (2 x 36" culverts)

Pipe Dimensions			
Diameter:	36	in	
	3	ft	
Radius:	1.5	ft	
# of Pipes:	2		
Initial Elev:	23.98	ft	
Terminal Elev:	23.35	ft	
Δ Elevation:	0.63	ft	
Length:	52	ft	

Converter			
gpm	0		
cfs	0		
cfs	0		
gpm	0		

Flow Depth (2yr):		
y:	6.2	in
	0.516	ft
θ:	1.711395	

Flow Depth (10yr):		
y:	8.8	in
	0.737	ft
θ:	2.07493	

Flow Depth (25yr):			
y:	10.4	in	
	0.867	ft	
θ:	2.26994		

Manning's Equation (2yr):			
n:	0.013		
A:	0.811	sqft	
R:	0.316	ft/ft	
S:	0.0121	ft/ft	
Q Total:	9.50	cfs	
Q Req/Pipe:	4.75	cfs	
Q =	4.75	cfs	
V =	5.854	ft/s	

_			
	Manning's Equation (10yr):		
	n:	0.013	
	A:	1.349	sqft
	R:	0.434	ft/ft
	S:	0.0121	ft/ft
	Q Total	19.50	cfs
Q	Req/Pipe:	9.75	cfs
	Q =	9.75	cfs
	V =	7.226	ft/s
	·		

Manning's Equation (25yr):					
n:	0.013				
A:	1.693	sqft			
R:	0.497	ft/ft			
S:	0.0121	ft/ft			
Q Total	26.80	cfs			
Req/Pipe:	13.40	cfs			
Q =	13.40	cfs			
V =	7.917	ft/s			

Travel time = 0.15 min	
------------------------	--

Travel time	= 0.12	min

# Attachment 4

**RUSLE Calculations** 



Subject: RUSLE Calculation – Yorktown Ash Landfill SWP #457				
lob No	1000 6405	Made By: DPM	Date: 8/3/15	
Job No. 1239-6405		Checked: KAL	Date: 6/6/16	
Ref:		Checked. KAL		
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		1	1	

Sheet

of

1

Reviewed: JRD

#### **OBJECTIVE**

To compute the expected amount of soil to be lost from the site after closure, by using the Revised Universal Soil Loss Equation (RUSLE).

#### **METHOD**

RUSLE is an empirically derived formula based on several decades of field research by the National Resource Conservation Service (NRCS). It is based on several site-specific factors involving precipitation, soil type, slope, and cover/conservation practices employed.

#### **REFERENCES**

1. <u>Predicting Soil erosion by Water: A Guide to Conservation Planning With the Revised Universal Soil Loss Equation (RUSLE)</u> USDA Handbook Number 703 (AH-703), July 1996.

#### **CALCULATIONS**

The RUSLE equation is as follows:

#### A=R\*K\*LS\*C\*P

Variable	Description	Value Used	
Α	soil loss in tons/yr/acre	-	
R	Rainfall-Runoff erosivity factor	250 (for York County, VA)	
K	Soil Erodibility factor	0.30 (aggregate)	
LS	Slope Length/Steepness factor	0.37 (2% slope, 400' long, moderate rill to interrill erosion (Table 4-2))	
С	Cover management factor	.005 (good stand of dense grass)	
Р	Support Practice Factor	1.0 (no specific measures)	

Values for each of the above variables were chosen based on guidance presented in AH-703. Soil erodibility factor (K) was selected as an aggregate average value of soils in the vicinity of the Facility, based on the NRCS's Web Soil Survey website.

#### **RESULTS**

A=250\*0.30\*0.37\*.005\*1.0 = 0.14 tons/acre/year

#### **CONCLUSIONS**

The landfill final cover as designed meets the criteria of less than two tons of soil loss per acre per year.

**Attachment 8** 

**Closure Cost Estimate** 



# Solid Waste Disposal Facility Cost Estimate Form

Facility I	Facility Name: Yorktown Power Station Ash Landfill Permit No. SWP 457								
Address	Address: 2347 Wolftrap Road								
City:	City: Yorktown State: VA Zip: 23692								
FA Hold	FA Holder: Dominion Resources Services, Inc.								
Estimate	e Prep	ared By:	Golde	er Associate:	lnc.				
Indicate	the p	lan version	s for w	hich this co	st estimate wa	as prepared, ide	ntifying the follow	ng informatior	n for eachplan.
Closure	e Plar	1				Post-Closure	Care Plan		
Title:		Yorktown /	Ash Lar	ndfill Closure	Plan	Title:	Yorktown Land	fill Post-Closur	e Care Plan
Plan Dat	te:	March 201	18	Approved:		Plan Date:	March 2018	Approved:	
Consulta	ant:	Golder Ass	sociates	s Inc.		Consultant:	Golder Associa	tes Inc.	
Correct	tive A	ction Plan	n			Corrective A	ction M niori ng	Plan	
Title:		n/a				Title:	n∌		=
Plan Dat	te:		1	A pproved:		Plan Date:		Approved:	
Consulta	ant:	_	_			Consultant:			
Cost Es	timat	te Summa	гу						
Total Clo	osure	Cost:			\$5,064,261				
Total Po	st-Clc	sure Cost:			\$6,281,794	4			
Total Co	rrecti	ve Action C	ost:		\$0		34 — (# #		
16.660	(	TOT	ΓAL:	\$	11,346,055				
Referei	nces					234			
			17.61				nstruction bids for		1000
Yorktow	vn ash	landfill 20:	17 clos	ure construc	tion and othe	er recent landfill	construction proje	cts in the cons	ultant's area.
		•							
Contific	ration	by Prepa	rate		1000	43 1 1 1			3/10/25
				ctimates per	taining to the	onginooring for	tures and monitor	ing roduiromo	nte of this solid
			the state of the s		A STATE OF THE STA		tative of the design		11 MAGE 196
				1.0	40.		te is based on the o	•	
							of wastes, facility s		
or other	r facili	ty assets at	the tir	me of partial	or final closu	re. In my profes	sional judgment, t	he cost estima	tes are a true,
							e, post-closure car		
the facility and comply with the requirements of 9 VAC 20-70 and all other DEQ rules and statutes of the Commonwealth									
of Virginia.									
Name:	-	iel McGrath	*			Signature:	Narul M	Shall	
Title:		crate and S				Date.	3/6	/18	
Al Charles	wledg	ement by	Owne	r/Operato		The second			1434
Name:	Da	vid Craym	ner			Signature:	Naul (	Klym	
Title:	Vi	ce Preside	nt, Sys	tem Operat	ions	Date: 03/15/	18	1	

#### Worksheet CEW-01: FORMAT FOR THE ESTIMATION OF CLOSURE COSTS

#### \*FILL IN THE BOXES. THE REST WILL BE CALCULATED FOR YOU\*

Soil	Cap Components			
I.	Slope & Fill		Calculation or Conversion	
a.	Area to be capped	19.6 acres	x 4,840yd2/ac	94,864 yd2
b.	Depth of soil needed for slope and fill	6 inches	x 1yd/36in	0.17 yd
c.	Quantity of soil needed		a x b	15,811 yd3
d.	Percentage of soil from off-site	33%		
e.	Purchace unit cost for off-site material	\$15.00 /yd3		
f.	Percentage of soil from on-site		(1 - d)	67%
g.	Excavation unit cost (on-site material)	\$5.00 /yd3		0
h.	Total soil unit cost		$(d \times e) + (f \times g)$	\$8.30 /yd3
i.	Hauling, Placement and Spreading unit cost	\$3.00 /yd3		0
j.	Compaction unit cost	\$0.62 /yd3		
k.	Total soil unit cost		h + i + j	\$11.92 /yd3
I.	Soil subtotal		k x b	\$188,463
m.	Percent compaction	10%		
	Total Slope & Fill Cost		l x (1 + m)	\$207,309
II.	Infiltration Layer Soil			
Infilti	ration Soil Cost			
a.		19.6 acres	x 4,840yd2/ac	94,864 yd2
b.	Depth of infiltration soil needed	0 inches	x 1yd/36in	0.00 yd
С.	Quantity of infiltration soil needed		a x b	0 yd3
d.	Percentage of soil from off-site	100%		
e.	Purchace unit cost for off-site material	\$18.00 /yd3		
f.	Percentage of soil from on-site		(1 - d)	0%
g.	Excavation unit cost (on-site material)	\$0.00 /yd3		
h.	Total infiltration soil unit cost		$(d \times e) + (f \times g)$	\$18.00 /yd3
i.	Hauling, Placement and Spreading unit cost	\$3.00 /yd3		
j.	Compaction unit cost	\$0.62 /yd3		
k.	Total infiltration soil unit cost		h + i + j	\$21.62 /yd3
I.	Infiltration soil subtotal	100	k x b	\$0
m.	Percent compaction	10%		40
n.	Subtotal Infiltration Soil Cost		l x (1 + m)	\$0
Soil A	dmixture Cost			
0.	Area to be capped	0 acres	x 4,840yd2/ac	0 yd2
p.	Soil admixture unit cost	\$2.85 /yd2		
q.	Subtotal admixture cost		a x b	\$0
Soil T	esting			
r.	Area to be capped	19.6 acres		
s.	Testing unit cost	\$2,500.00 /acre		
t.	Subtotal soil testing cost	_ <del></del>	a x b	\$49,000
	Total Infiltration Soil Cost (soil, admixtures, a	nd testing)	n + q + t	\$49,000

III.	<b>Erosion Control / Protective Cover Soil</b>			
a.	Area to be capped	19.6 acres	x 4,840yd2/ac	94,864 yd2
b.	Depth of soil needed	18 inches	x 1yd/36in	0.50 yd
c.	Quantity of soil needed		a x b	47,432 yd3
d.	Percentage of soil from off-site	100%		
e.	Purchace unit cost for off-site material	\$27.00 /yd3		
f.	Percentage of soil from on-site		(1 - d)	0%
g.	Excavation unit cost (on-site material)	\$0.00 /yd3		
h.	Total erosion/protective soil unit cost		$(d \times e) + (f \times g)$	\$27.00 /yd3
i.	Hauling, Placement and Spreading unit cost	\$3.00 /yd3		
j.	Compaction unit cost	\$0.62 /yd3		
k.	Total soil unit cost		h + i + j	\$30.62 /yd3
l.	Erosion/Protective soil subtotal		k x b	\$1,452,368
m.	Percent compaction	10%		
	Total Erosion Control/Protective Cover Soil Cost		l x (1 + m)	\$1,597,605
IV.	Vegetative support soil (Topsoil)			
a.	Area to be capped	19.6 acres	x 4,840yd2/ac	94,864 yd2
b.	Depth of topsoil needed	6 inches	x 1yd/36in	0.17 yd
c.	Quantity of topsoil needed		a x b	15,811 yd3
d.	Percentage of topsoil from off-site	100%		10,011 740
e.	Purchace unit cost for off-site material	\$28.00 /yd3		
f.	Percentage of topsoil from on-site	<del>- γ20.00</del> γ γ α.σ	(1 - d)	0%
g.	Excavation unit cost (on-site material)	\$0.00 /yd3	(= =/	
h.	Total topsoil unit cost	70.00	(d x e) + (f x g)	\$28.00 /yd3
i.	Hauling, Placement and Spreading unit cost	\$3.00 /yd3	(* -7 ( 6)	, , , ,
j.	Total soil unit cost		h+i	\$31.00 /vd3
,	Total Topsoil Cost		схј	\$490,131
V.	Vegetative Cover			
a.	Area to be vegetated	19.6 acres		
b.	Vegetative cover (seeding) unit cost	\$3,250 /acre		
c.	Erosion control matting unit cost	\$6,000 /acre		
	Total Vegetative Cover Cost		a x (b + c)	\$181,300.00

Soil Cap Component Subtotal (I + II + III + IV + V): \$2,525,345

synthetic Barrier & Infiltration Layers				
Flexible Membrane Liner		Calculation or Conversion		
Quantity of FML needed	21.56 acres (+10%)	x 43,560ft2/ac	939,154 ft2	
Purchase unit cost	\$0.26 /ft2			
Installation unit cost	\$0.18 /ft2			
Total FML unit cost		b + c	\$0.44	
Total FML cost		a x d	\$413,228	
Geosynthetic Clay Liner				
Quantity of GCL needed	0 acres	x 43,560ft2/ac	0 ft2	
Purchase unit cost	\$0.00 /ft2			
Installation unit cost	\$0.00 /ft2			
Total GCL unit cost		b + c	\$0.00 /ft2	
Total GCL Cost		a x d	\$0	
	Flexible Membrane Liner Quantity of FML needed Purchase unit cost Installation unit cost Total FML unit cost Total FML cost  Geosynthetic Clay Liner Quantity of GCL needed Purchase unit cost Installation unit cost Total GCL unit cost	Flexible Membrane Liner  Quantity of FML needed  Purchase unit cost  Installation unit cost  Total FML unit cost  Geosynthetic Clay Liner  Quantity of GCL needed  Purchase unit cost  Installation unit cost  Total GCL unit cost  Total GCL unit cost	Flexible Membrane Liner  Quantity of FML needed  Purchase unit cost Installation unit cost  Total FML cost  Geosynthetic Clay Liner  Quantity of GCL needed  Purchase unit cost  Total GCL unit cost  D acres  Calculation or Conversion  x 43,560ft2/ac  x 43,560ft2/ac  acres  x 43,560ft2/ac  Acres  purchase unit cost  \$0.00  ft2  b + c  b + c  b + c	Flexible Membrane Liner  Quantity of FML needed  Purchase unit cost  Installation unit cost  Total FML unit cost  Geosynthetic Clay Liner  Quantity of GCL needed  Purchase unit cost  Quantity of GCL needed  Purchase unit cost  Geosynthetic Clay Liner  Quantity of GCL needed  Purchase unit cost  Total GCL unit cost  So.26  /ft2  b + c  \$0.44  a x d  \$413,228    Total FML cost  \$0.00  /ft2    ft2    ft2

Geosynthetic Layers Subtotal (VI + VII): \$413,228

**Drainage Components** 

VIII.	Sand or Gravel Drainage		alculation or Conversion	
a.		19.6 acres	x 4,840yd2/ac	94,864 yd2
b.	Depth of sand or gravel needed	0 inches	x 1yd/36in	0.00 vd
c.	Quantity of drainage material needed	<u> </u>	a x b	0 yd3
d.	Percentage of media from off-site	100%	u // u	c 745
e.	Purchace unit cost for off-site material	\$16.49 /yd3		
f.	Percentage of material from on-site	<del>, , , , , , , , , , , , , , , , , , , </del>	(1 - d)	0%
g.	Excavation unit cost (on-site material)	\$0.00 /yd3	(/	
h.	Total drainage material unit cost	, , , , , , ,	(d x e) + (f x g)	\$16.49 /yd3
i.	Hauling, Placement and Spredding unit cost	\$1.65 /yd3	(* -) ( 0)	, , ,
j.	Compaction unit cost	\$0.82 /yd3		
k.	Total drainage material unit cost	r ,	h + i + j	\$18.96 /yd3
I.	Drainage material subtotal		k x b	\$0.00
m.	Percent compaction	10%		
	Total drainage material cost		l x (1 + m)	\$0
X.	Geotextile			
a.	Quantity of geotextile needed	0 acres	x 43,560ft2/ac	0 ft2
b.	Purchase unit cost	\$0.11 /ft2		
c.	Installation unit cost	\$0.05 /ft2		
d.	Total geotextile unit cost		b + c	\$0.16 /ft2
	Total Geotextile Cost		a x d	<i>\$0</i>
ζ.	Geonet Composite			
a.	Quantity of geonet composite needed	21.56 acres (+10%)	x 43,560ft2/ac	939,154 ft2
b.	Purchase unit cost	\$0.45 /ft2		
c.	Installation unit cost	\$0.12 /ft2		
d.	Total geonet composite unit cost		b + c	\$0.57 /ft2
	Total Geonet Composite Cost		a x d	\$535,318
I.	Drainage Tile (cap drains)			
a.	Length of drainage tile needed	660 LF		
b.	Purchase unit cost	\$20.00 /LF		
c.	Trenching and backfilling cost	\$25.00 /LF		
d.	Total drainage tile unit cost		b + c	\$45.00 /ft2
	Total Drainage Tile Cost		a x d	<i>\$29,700</i>

#### XII. Drainage Channels (Stormwater Control)

Drain	age benches and berms			
a.	Length of drainage bench needed	4,336 LF		
b.	Drainage bench unit cost	\$25 /LF		
c.	Subtotal drainage bench cost		a x b	\$108,400
d.	Length of 24" drainage pipe needed	300 LF		
e.	Drainage pipe unit cost	\$85 /LF		
f.	Subtotal drainage swale/berm cost	<u></u>	d x e	\$25,500
Rip Ro	ар			
g.	Quantity of Rip Rap needed	100 yd2		
h.	Rip rap unit cost	\$35.00 /yd2		
i.	Total rip rap cost		gxh	\$3,500
Gabia	n Baskets			
j.	Quantity of gabian baskets needed	0 yd3		
k.	Gabian basket unit cost	\$55.00 /yd3		
I.	Subtotal gabian basket cost		j x k	\$0
	Total Stormwater Control		c + f + i + l	\$137,400

Drainage Component Subtotal (VIII + IX + X + XI+ XII): \$702,418

#### Landfill Gas and Groundwater Features

Land	fill Gas and Groundwater Features				
XIII.	Landfill Gas Monitoring & Control Compon	ients	Calculation		
Landf	ill Perimeter System				
a.	Number of probes to be installed	0 probes			
b.	LFG probe unit cost	\$1,099 /probe			
c.	Subtotal LFG probe cost		a x b	\$0	
Landf	îll Control Systems				
d.	Area to be closed	28 acres			
e.	Average number of vents per acre	0 vents / acre			
f.	LFG vent unit cost	\$3,518 /vent			
g.	Subtotal LFG vent cost		d x e x f	\$0	
h.	Length of header pipe needed	- LF			
i.	Header pipe unit cost	\$2.79 /LF			
j.	Header pipe installation cost	\$5.59 /LF			
k.	Subtotal LFG active vent hook-up		h x (i + j)	\$0	
	Total Landfill Gas Management Cost		c + g + k	\$0	
XIV.	<b>Groundwater Monitoring Components</b>				
a.	Hydrogeologic study cost	\$0			
b.	Number of wells to be installed	0 wells			
c.	GW Monitoring Well unit cost	\$1,270 /well			
d.	Number of wells > 50 ft length	0 wells			
e.	Additional well length over 50 ft	0 LF/well			
f.	Unit cost for additional well length	\$25 /LF			
	Total Groundwater Monitoring Well Cost		$a + (b \times c) + (d \times e \times f)$	\$0	

Landfill Gas & Groundwater Features Subtotal (XIII + XIV):

**\$0** 

#### Miscellaneous

XV.	Removal and Disposal of Stockpiled Mate	rial	Calculation		
a.	Quantity of stockpiled materials	- vd3	<u> </u>		
b.	Loading and Hauling unit cost	\$1.68 /yd3			
c.	Disposal unit cost	\$25.40 /yd3			
d.	Total Removal/Disposal Cost	,	a x (b + c)	\$0	
XVI.	Erosion/Sediment Control				
a.	Quantity of silt fence needed	7,500 LF			
b.	Silt Fence unit cost	\$3.50 /LF			
	Total Silt Fence Cost		a x b	\$26,250	
XVII.	Landfill Access Road				
a.	Size of LF access road	1,250 yd2			
b.	1 0	6 inches	x 1yd/36in	0.2 yd	
c.	Depth of asphalt needed	0 inches	x 1yd/36in	0.0 yd	
d.			a x (b + c)	208 yd3	
e.	Road material unit cost	\$35.00 /yd3			
f.	Placement/Spreading unit cost	\$3.56 /yd3			
	Total access road cost		c x (d + e)	\$8,033	
	. Site Security				
Fencii					
	Length of fencing needed	- IT			
	Fence unit cost	\$15.24 /ft	b	ćo	
C.	Subtotal fencing cost		a x b	\$0	
Gate d	or Barrier				
d.	Number of gates required	1			
e.	Gate unit cost	\$1,219.20 /gate			
f.	Subtotal gate cost		d x e	\$1,219	
Closed	l Sign				
g.	Number of signs required	2			
h.	Sign unit cost	\$75.00 /sign			
i.	Subtotal sign cost		g x h	\$150	
	Total site security cost		c + f + i	\$1,369	
XIX.	Mobilization / Demobilization				
a.	Cost for mobilization/demobilization	\$225,000			
	Total mobilization/demobilization cost			\$225,000	
			Miscellaneous Subtotal (X	XV + + XIX):	\$261,871

**Closure Cost Subtotal (CCS):** (I + ... + XIX) \$3,902,861 **City Cost Index (Small City)** 100%=1 \$3,902,861 **Adjusted Closure Cost (ACC)** Contingency (10%): CCS x 0.10 \$390,286 Adjusted Closure Cost + Contingency (ACC+C) \$4,293,147 **Engineering & Documentation:** Construction QA/QC \$12,500 / Acre \$600,000 Closure Certification and CQA Report (1%) ACC x 0.01 \$39,029 ACC x 0.03 \$117,086 Survey and as-builts (3%) \$15,000 Cost for survey and deed notation **Total Engineering & Documentation Costs** \$771,114